Information management for creative stimuli in engineering design

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Award date:
2008

Awarding institution:
University of Bath

INFORMATION MANAGEMENT FOR CREATIVE STIMULI IN ENGINEERING DESIGN

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A thesis submitted for the degree of Doctor of Philosophy

University of Bath

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April 2008

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In loving memory of my Grandfather Charles Allman
who died during my final year of study.

His support and enthusiasm for my work will be greatly missed.

Abstract

This thesis describes research carried to investigate the role of creative stimuli in the engineering design process. The research was cross-disciplinary bringing findings and perspectives from cognitive psychology to engineering design. The theoretical work undertaken has produced a model to represent how information can be made to work effectively as creative stimuli, inspiring creative ideas that in turn affect the design outputs produced through the creative design process.

By combining participation action research with an observational audit, the information-use *profiles* were constructed for the innovation hub within the associated case company. These gave details of the types of projects and tasks undertaken by the case company; the designers working on them, and most importantly the information being used during design activities. It was shown that over 50% of the information uses recorded were working on diagrammatic representations, predominantly using CAD and imaging software.

In this thesis it is shown that information captured, documented and stored by a company can be used as a useful source of creative stimuli. A tool was proposed to retrieve this information in a *guided* manner to support creative idea generation in industrial brainstorm sessions. The evidence suggested that introducing any of the tested formats of stimuli to a brainstorm group had positive affect on both the rate of idea production and the quality of the ideas being produced. Stimuli *sourced internally* to the case company in a *guided* manner were shown to perform as well as the most established creative stimuli tools available.

Acknowledgements

Firstly, the author would like to thank supervisors Professor Steve Culley and Dr Elies Dekoninck for their continual support throughout this PhD. Whilst offering guidance, they also provided a belief and a freedom to explore.

In addition, the author would like to thank Mike Curtis, Chris Ramsey, Katie Bodnar, Alex Paris and colleagues at Crown Packaging, UK for their time, financial support and interest in the research. The author would also like to thank colleagues and friends at the University of Bath.

Finally, thanks to my family, Frank Howard, Katrina Howard and Mat Howard along with my partner Danielle Chandler for their patience and understanding.

The work reported in this thesis has been undertaken as part of the EPSRC Innovative *Design* and Manufacturing Research Centre (I*d*MRC) at The University of Bath (grant reference EP/P500036/1).

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Glossary

This section lists important terminology related to this research. Each term will be used within the main text and will be capitalised to inform the reader that a specific definition has been made for the term.

Tern	Definition
Stimuli	Information used to inspire idea generation.
Idea	An idea is a creative output and is a generative proposition linked to the function, behaviour or structure of a concept.
Creative Idea	An Original, Appropriate and Un-Obvious idea.
Routine Idea	An idea that is not deemed creative.
Originality	The first idea associated to a particular concept.
Appropriateness	An idea that is deemed useful and implementable.
Un-Obviousness	An idea that take time to form.
Location	Where information is located for association.
Inner	Cognitive information, located within memory.
Outer	Information located in surrounding environment.
Apparentness	How obviously related stimulus is to the problem at hand.
Relevance	How related stimuli is to a problem.
Source	An outer repository of information.
Internal	Information sourced from within the industrial domain of the problem at hand.
External	Information sourced from another domain from that of the problem at hand.
Retrieval	The method by which stimuli is sourced and prompted.
Random	An ad-hoc and unstructured approach to retrieving stimuli.
Guided	A logical approach to sourcing and retrieving stimuli with intension to find relatively more effective stimuli.
Major Area	One of the factors in the highest level of classification that affects the performance of creative stimuli. There are three Major Areas.
Characteristic	A breakdown of the different interactions between the Major Areas. There are 7 characteristics.

Variable	An aspect of a characteristic that can be changed affecting the performance of the stimuli.
Framework	An umbrella term used to describe all levels of influence on stimuli (Major Areas, Characteristics and Variables).
Success Criteria	The measurable criteria that determines the performance of the creative stimuli.
Profile	Data set from the observational information audit set regarding the Major Area under study.
Type A tool	A creativity support tool that Randomly prompts stimuli in from External Sources.
Type B tool	A creativity support tool that Randomly prompts stimuli in from External Sources.
Type C tool	A creativity support tool that Randomly prompts stimuli in from External Sources.
Type D tool	A creativity support tool that Randomly prompts stimuli in from External Sources.
Brainstorm	A technique used to support the creative process, based on differing judgment of Ideas proposed.
alpha-idea	An idea produced during free thinking brainstorming.
beta-idea	An idea produced by brainstorming when subjected to prepared stimuli.
gamma-idea	An idea produced individually away from the brainstorm group.
delta-idea	An idea generated from combining ideas from concepts in a review meeting.
Concept	A representation of a solution comprising of functional, behavioural and structural Ideas.
Gate Concept	A Concept selected for presentation at the case company stage gate meeting.
Gate Idea	An Idea that belongs to a gate concept.

The secret to creativity is knowing how to hide your sources.

Albert Einstein

1 Introduction

In October 2007 an independent review of Science and Innovation was published by Lord Sainsbury (2007). The review resulted in a further £1bn governmental investment over the next 3 years to drive innovation (HM Treasury 2008), specifically promoting "*a new technology strategy for turning good ideas into new products*" (Sainsbury 2007). This continual investment in innovation illustrates its importance.

In the lead up to this research, it has become widely accepted that business survival and prosperity is strongly attributed to the ability to innovate (Prahalad and Ramaswamy 2003; Campos *et al.* 2004; Soosay and Hyland 2004; Taghavi *et al.* 2004). In order to harness this ability, many engineering companies have specific innovation and R&D departments, developing new products through strategically constructed innovation processes. However, without creative individuals and teams generating creative Ideas throughout the process, the outputs may not have the required impact.

The process of generating creative Ideas is enhanced by providing creative individuals three main elements; nurture, freedom (Mauzy and Harriman 2003) and time (Sternberg and Lubart 1993; Frey 1999). However, such is the nature of industry that time pressures often dominate, requiring rapid Idea and concept generation from engineering designers. The need for increased quality of Ideas is compromised by the time in which they are to be produced. Thus creative tools are required to aid the designer to produce more 'creative' ideas in short periods of time. This thesis examines an approach to aid creative Idea generation in engineering design.

This section first details the background in terms of the three main subject areas of, engineering design, creative Idea generation and information management in which the research relates. The research into creative Stimuli is then summarised in terms of the three major critical dimensions namely, the knowledge gap that the research

addresses and the creativity support tool developed making use of this knowledge gap (section 1.2). In section 1.3 the overall aims of the research are laid out, leading in to a detailed industrially based research methodology in section 1.4.

1.1 Background

The work described within this thesis is cross disciplinary research from the domains of cognitive psychology and engineering design. There are distinct knowledge gains to both communities and as such, this section is structured to make the research more accessible from both perspectives.

Figure 1-1 describes the key areas being researched. This was generated using the 9 windows system operator tool from TRIZ[1] (Altshuller 1999), to define the system in which the problem lies. Here it can be seen that the system under-study is creativity, which is affected by the subsystem 'information' and affects the supersystem of 'design'. Running from left to right is the increasing development or understanding of the system. The 9 windows systems operator is particularly powerful as it highlights other areas in which the problem could be solved; thus to increase creativity the research could focus on creative 'stimuli'.

Super System	Task	**Design**	Solution
System	Stimuli	**CREATIVITY**	Idea
Sub System	Data	**Information**	Knowledge

Understanding →

Figure 1-1 – 9 Windows System Operator

The focus of this study is Creativity shown in as the central 'system' (the system being the focus area of study). It is proposed in later chapters that this is affected by

[1] TRIZ – Russian acronym for theory of inventive problem solving.

the subsystem 'information' and as stated in the introduction is a key component to design. The major areas of interest to be considered are:

- the linking of the super system of design to the system, creativity (section 1.1.1),
- the system of creativity itself (section 1.1.2) and,
- the linking of the subsystem, information, to the system, creativity (section 1.1.3).

These issues are briefly addressed in the following sections of the introduction and are considered in more detail in the extensive literature review in chapters 2 and 3.

1.1.1 Creativity in design

In order for firms to increase their organisational creativity thus resulting in enhanced innovation (Bharadwaj and Menon 2000), the creative process of individuals must be considered within the design process. The presence of the right kinds of organisational systems, procedures and processes can lead to strengthened creative efforts of individuals (Amabile 1989).

To frame the system, creativity, TRIZ states it must be looked at with reference to the super-system, in this case, design. This is a useful separation as the terms 'to create' and 'to design' are often confused, particularly between engineers and social scientists. Whilst in engineering there are large numbers of design process models, only one model reviewed (see chapter 2) was integrated with the creative process. It is instead commonly assumed that creativity is something that occurs somewhere within the conceptual design stage of the engineering design process.

Whilst participating in engineering and social science (cross disciplinary) creativity cluster meetings (Johnson 2006), it was clear that many social scientists could not distinguish between creativity and design. There was no realisation that design is a process of developing Ideas, with Ideas being the outcome of the creative process. The design process mainly referred to in this thesis generally consists of a succession of design operations between and within functions, behaviours and structures. It is proposed that stages of the creative process occur at each of these design operations.

1.1.2 Creativity

For any study dealing with creativity, a definition is essential. A broad definition might be that it concerns the production of novel Ideas that are in some sense useful or an advance beyond previous conceptions (Eysenck and Keane 2000). However, there are a wide variety of definitions, over 200 in the literature alone (Goldenberg and Mazursky 2002). It is the author's view that it is rarely useful to generically define creativity; instead creativity must be more specifically defined to suit the particular study and domain. In particular, the typology of research in the engineering design field has been categorised by Ullman (1997) into; Person, Process, Output and Environment.

For this research the author has narrowed the scope to concentrate on the Creative Output and Process focusing on individual creativity. Whilst the character traits of creative individuals (Person) and the effects of factors such as social creativity (Environment) are extremely valuable areas of research, in this work they are factors to be controlled rather than tested. Social interaction will be considered as a dynamic flow of information. The creative outputs are considered to be stimulated not by another person but the information obtained from that person.

The creative output commonly called the 'creative product' in psychology literature will be established by a three attributes for this research. It is proposed by the author that an Idea must be Original, Appropriate and Un-Obvious (Howard *et al.* 2006) if it is to be deemed creative as apposed to routine. This definition was carefully developed from the literature. It is specific to the research as it best suits the hypothesis and the area of creativity under study. It was also chosen to closely relate to the three requirements of patent approval.

The creative Idea generation process proposed by the author (section 3.3) is described by using a simple cognitive model representing information Sources used for stimulation. Whilst it does not reference the four stages of preparation, incubation, illumination and verification (Wallas 1926) commonly found in creative process models, it runs parallel along side the first three stages.

1.1.3 Information in creativity

The linking of the 'system', creativity, to its 'sub-system' of information (Figure 1-1) is the main focus of the research. The creative process, described in section 1.1.2, distinguishes between the mechanisms of creative Idea production and routine Idea production by analysing the information used to form the association.

The types of information used can be categorised against two criteria "Apparent-Relevance" and "Location" as shown in Table 1-1. Apparent-Relevance is the criterion that combines the two attributes of Un-Obviousness and Appropriateness used in the definition of creative output in section 1.1.2. Location refers to the position or source of the information on access, Inner being cognitively stored, Outer being experienced from outside the human body.

		Location	
		Inner	Outer
Apparent - Relevance	High	Working Memory	Task Information
	Low	Long Term Memory	Surrounding Information

Table 1-1 – Information Types (Howard *et al.* 2006)

The research shows that the key difference between stimulating information which produces creative Ideas, over suppressive information producing routine Ideas is over the factor of what will be called Apparent-Relevance. It is proposed that information must be Un-Apparently Relevant to stimulate a creative Idea. However, it is also hypothesised that it is to the detriment of the Appropriateness of the Ideas produced. This theme of using information (or Stimuli) to stimulate creative Idea generation is central to this research.

1.2 Creative stimuli

This section will describe to the reader the more specific area that the research contributes. During the theoretical work or chapter 2, the importance of creative Idea generation is described with respect to engineering design. In chapter 3, a theoretical

model (section 3.3) is proposed directly linking information (as an input) to creative Idea generation. This model also helped to describe how information accessed Outer to the mind could act as creative Stimuli. The subsequent studies proceeded to investigate into the attributes of this information and the consequent affects.

1.2.1 Three Major Areas affecting creative stimulation

A framework was constructed representing the author's understanding of the system from the experience and the literature review undertaken. The framework consisted of the three Major Areas affecting creative stimulation (Figure 1-2) of, the information, the design task and the designer. The diagram (Figure 1-2) shows how these Major Areas overlap producing seven theoretical combinations of the information, task and designer characteristics that may affect design information in terms of its stimulating potential to creative Idea generation. This is the outline of a complete Framework described thoroughly in chapter 4.

The variables associated to the characteristics in position (1), central to Figure 1-2, are thought to be of the most influential to creative idea stimulation. Two of these variables of Apparentness and Relevance of information (section 1.1.3) are used to differentiate between Stimuli generated Internally and Externally to the company or industrial domain (see section 6.4).

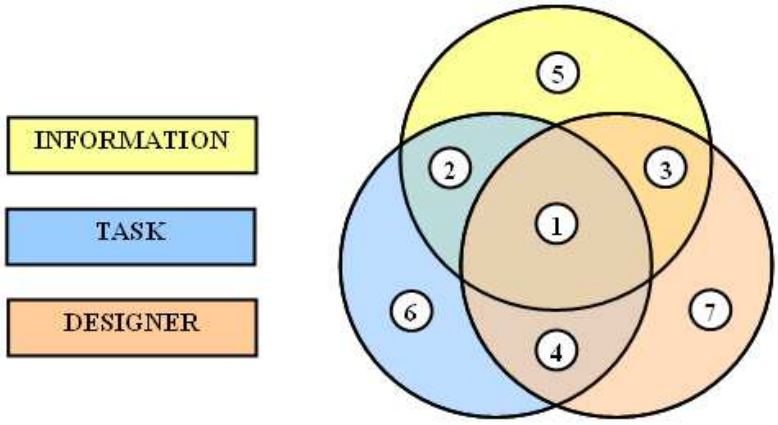


Figure 1-2 – Stimuli characteristics and the 3 Major Areas

1.2.2 Knowledge gap

When researching into creativity support tools (section 6.1), three distinct categories of tools emerged. One of these categories was the creative Stimuli tool. These particular tools all worked by proposing Stimuli retrieved by logical or Guided mechanism or Stimuli retrieved on a Random basis. The TRIZ contradiction matrix is perhaps the most interesting of these Guided Stimuli tools. However there are common complaints from practitioners that the methods are time consuming and the Stimuli proposed are often too difficult to relate to the problem. This was a major driver for the Information Management Creative Stimuli (IMCS) tool (see section 1.2.3) designed during the prescriptive study (chapter 6).

It was also observed, that all identified Stimuli tools currently available propose Stimuli from Sources External to the domain of the problem, in positions A and B in Table 1-2. This provides a gap in research for Stimuli proposed form Internal Sources. Though it is common for engineers to search their environment and for inspiration from say, magazines, catalogues, prototypes etc. it had occurred that this was not done in a systematic way.

This gave rise to the potential of two different types of creative Stimuli tools, in positions C and D (Table 1-2) sourcing Stimuli from within the domain of the problem or even from within the company's information management system.

		Retrieval	
		Random	Guided
Source	External	A	B
	Internal	C	D

Table 1-2 – Matrix of creative stimulus

Source – where the Stimuli are drawn from. This can either be Internal or External to the industrial domain in which the task is set.

Retrieval – how specific the retrieval mechanism is to the task. The Stimuli can either be retrieved by Random, or, Guided by an abstracted framework making it (theoretically) more affective to the task at hand.

It is hypothesised that, stimulus Sourced Internal to the domain of the problem will be more Relevant, and thus more useful more often, providing that an adequate tool can be constructed for its search and retrieval (chapter 6).

1.2.3 Creative stimuli tool

As an objective of the research, a tool was to be designed to technology readiness level 2 (Mankins 1995). This was predominantly to investigate the potential of the types of Stimuli being tested, but also to provide benefit to the case company and to demonstrate the possible implementation of the research. The creative Stimuli tool Sourced information Internal to the company using a Guided approach. It was given the name Information Management Creative Stimuli (IMCS) tool.

The IMCS tool relies on several conditions, all of which were fulfilled by the case company. Firstly, the company must have a consistent and standard design process. Secondly, the documents containing the project brief, the designed ideas and concepts and must be consistently and appropriately named and must be stored electronically and logically.

Where the TRIZ contradiction matrix uses abstracted design contradictions to link the current problem to previous problems, the IMCS tool creates this link by comparing 'musts' and 'desirables' from the design specifications. Though there are several methods by which to recall Stimuli in an intelligent, Guided manner, the method chosen is an example to provide a repeatable simulation of a Type D tool Table 1-2.

1.3 The overall aim of the research

From the previous reviews and discussion it is clear that this study will have the broad aim of understanding complex systems of design, creativity, information and idea generation from across research disciplines (section 1.3.1). More specifically the research will hope to address two major research questions (section 1.3.2) and nine key research objectives (section 1.3.3).

1.3.1 Research aim

The following statement describes the broad area of research that this thesis will deal with and will aim to:

"Gain greater understanding of the information use as creative stimuli as an input into the engineering design process"

1.3.2 Research questions

From this overall aim, two specific research questions are proposed to address the gaps identified (section 6.2) from other studies within this area. These are mainly dealt with in chapters 6 and 7.

1. Is it possible to manage information within a company to be used as stimuli to aid creative idea generation?
2. How effective will these stimuli be in comparison with the other approaches in current common practice?

1.3.3 Research objectives

The major objectives that will need to be addressed in order to fulfil the above aim and questions are:

Methodological

Objective A: To construct a bespoke and industrially based research methodology taking advantage of the resources of the industrial collaborator, Crown Packaging (section 1.4)

Theoretical

Objective B: To understand and describe the links between the creative engineering design process and a creative design output, merging theory from both cognitive psychology and engineering design literature (chapter 2)

Objective C: To describe the cognitive mechanism distinguishing a creative output from a routine output by the different categories of information (inputs) identified (chapter 3)

Objective D: Identify the Major Areas and the influential variables affecting creative idea stimulation, including the measurable variables and a robust definition for success criteria (chapter 4)

Objective E: To identify a distinct knowledge gap and to propose a support tool to test the research questions and hypothesis (section 6.4) in an industrial setting in addition to providing scope for future embodiments of the research (chapter 6)

Investigatory

Objective F: To analyse the information profile of the Crown Packaging Innovation department in terms of the 'Major Areas' identified in the criteria stage, to further understand the context under study (chapter 5)

Objective G: To show how ideas develop in free thinking brainstorm sessions in terms of the rate of idea generation and the Un-Obviousness, Appropriateness and Originality of ideas (section 7.3)

Objective H: To determine the effect of introducing Stimuli into a group brainstorming session, in comparison with the performance during free thinking brainstorming (section 7.4)

Objective I: To decipher which of the Stimuli types is identified to be most promising in terms of creative idea generation (section 7.5)

1.4 Research methodology

Choosing or designing the right methodology is of great importance; the wrong method could limit the researcher's understanding of the system under study, or make findings unsuitable to the wider community. This is partly because, whether or not an approach is appropriate depends on the research topics or questions being addressed (Avison *et al.* 1999). The approach taken in this research was designed to be opportunistic, taking advantage of the information and processes available from the industrial collaborator (section 5.1).

This section starts with an introduction into engineering design research (section 1.4.1). Generic methodologies are looked at (section 1.4.2), followed by the research

approaches adopted from literature (section 1.4.3). The final customised methodology is then described in section 1.4.4.

1.4.1 Engineering design research

The main task of engineers is to apply their scientific and engineering knowledge to the solution of technical problems, and then to optimise those solutions within the requirements and constraints set by material, technological, economic, legal, environmental and human-related considerations (Pahl and Beitz 1984, p1). This broad appreciation of the affected communities along with the unique and fuzzy[2] nature of design projects makes the process of engineering design extremely complex.

Although design is one of the fastest growing areas of research, for reasons stated above, the extent of research into its own research methodology is, with a few exceptions, limited (Blessing and Chakrabarti 1999; Blessing 2002). The lack of coherent guidance with regards to research methodologies can also be put down to the lack of maturity of the field of design research. However, there are more subtle problems such as the terminology issues. For this research the methodology (section 1.4.2) will describe the overall path of the research consisting of a variety of research methods or approaches (section 1.4.3) taken along the way.

1.4.2 Generic research methodologies

It is rarely appropriate to simply adopt a single research methodology. In its simplest and most well referenced form the standard engineering design research methodology is a three part cycle of Observe, Analyse and Intervene (Tang and Leifer 1991). In a slight evolution to this methodology it has been observed that as the methodology progresses, studies contain less observation and more analysis and intervention (Eris 2002). Figure 1-3 shows a very general outline which virtually all engineering design research methodologies follow.

[2] Design problems are commonly termed fuzzy, as the goal state is often unknown and the problem is often ill defined.

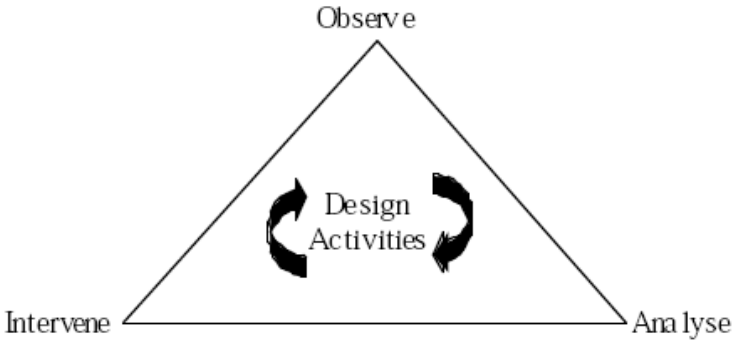


Figure 1-3 – Design research cycle (Tang and Leifer 1991)

A more detailed and useful methodology is that proposed by Blessing (1999) consisting of four stages (see Figure 1-4). The first begins beyond the point of the project proposal and the literature review and starts at the hypothesis stage where the criteria for research are to be decided. Beyond the criteria stage it takes on a typical Observe, Analyse, Intervene cycle which is split into descriptive and prescriptive stages. This methodology was selected for this research and was customised (section 1.4.4) to suite the industrial collaboration and the favoured research approaches (section 1.4.3).

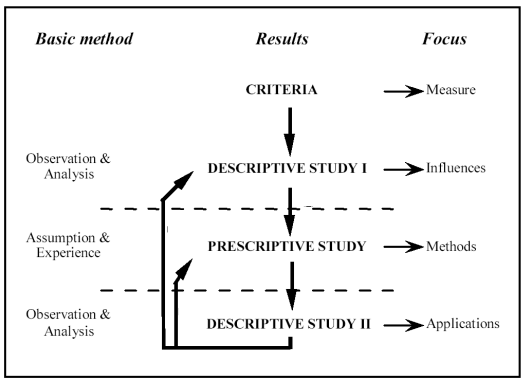


Figure 1-4 – Blessing's Generic Design Research Methodology

Criteria definition – This stage involves detailing and formulating success as well as measurable criteria (described in chapter 4).

Descriptive Study 1 – This stage involves increasing the understanding of design in order to inform the development of design support (described in chapter 5)

Prescriptive Study –This stage is concerned with the development of an impact model (or theory) and tools for design support in order to realise the desirable situation (described in chapter 6). In this case the term prescriptive study relates to developing what to prescribe rather than, as it is sometimes used, gauging the effect of what has been prescribed.

Descriptive Study 2 – This stage is concerned with a formal evaluation of the tools or methods developed from the Prescriptive Study to evaluate whether they achieve the expected effect and, in particular, their overall impact on the measurable criteria originally defined (described in chapter 7).

Though the criteria and prescriptive study stages are generally conducted theoretically, there are a multitude of research approaches that can be adopted for both descriptive study stages.

1.4.3 Research approach

In order to work with Crown Packaging an appropriate research methodology needed to be developed to address Objective A. It was realised that the research approach would have to be non obstructive. It would have to provide little to no hindrance to the working environment and where possible, provide benefit and expertise. Several initial approaches were not considered due to their obstructive nature such as diary studies and questionnaires. Other initial studies were abandoned due to their unrealistic and artificial nature such as the empirical study into word puzzles and retrospective reviews of case studies which describe and idealised sequence of events.

Many of the other studies reviewed (see sections 3.4 & 3.5) have attempted to research the topic in the field through empirical based studies. However, results and methods often seem artificial due to the lack of industrial grounding and the 'external' research approaches used (Ottosson 2003). With the industrial opportunity, it was decided that 'insider' research would be undertaken.

An increasingly popular research approach taken for engineering design studies is action research. Action research is said to provide the link between participation, social action, and knowledge generation (Greenwood *et al.* 1993). This research would adopt this approach of 'insider' or 'participation' action research (Bjork and Ottosson 2007). Here the emphasis is firmly on what designers do rather than what they say they do (Avison *et al.* 1999). This research is made effective by the extremely deep understanding gained for a single case and establishing internal validity, before extracting principles to test for external validity in future studies.

These studies are largely qualitative due to the setting in which action research is usually conducted. However, it is possible to triangulate research findings gained from a variety of different approaches (Bjork and Ottosson 2007), giving the effect of building up a picture from multiple viewpoints.

Another useful approach, identified as relevant to this study is protocol analysis. This is where protocol, commonly dialogue, is reviewed piece by piece to identify sequences of the measurable and success criteria. This approach has yielded some respected studies in this area (Benami and Jin 2002; Kim *et al.* 2005) as it provides a more realistic representation of actual occurrence than retrospective studies. This approach will be utilised in this research with the aid of video capture so group interaction can be recalled and the protocol analysed.

1.4.4 Customised research methodology

The following customised research methodology closely follows Blessings (2002) generic design research methodology. During the descriptive studies various research approaches will be adopted and are then both focused and complemented by the theoretical stages.

During earlier phases of the research, it was agreed that the author would undertake the first of a two part study comprising descriptive study 1 (Blessing and Chakrabarti 1999), acting as project manager for a Crown innovation project (see section 5.2). During this participation action research study, the primary goal was to become

familiar with the designers, projects, processes and information management systems at Crown.

Part 2 of descriptive study 1 presents an empirical study resulting from an observational, information audit (section 5). This was deemed the best way to identify the potential areas in which an information management system for creative Stimuli could take affect. The audit would account for information associated with the innovation department designers, the projects being worked on, the communication flow within the department, the Location of information access, along with the various other information characteristics.

Descriptive study 2 develops the opportunity for improvement as identified during descriptive study 1. The design support tool is then developed further through the prescriptive study (chapter 6). This study is focused on the group brainstorming session introducing stimulus of different information types for testing. The complete methodology can be seen in Figure 1-5, where each stage is attributed to a chapter of the thesis.

	Stage of Methodology	Output
Chapter 2	**Creativity in engineering design** – Literature review 1. The purpose of this literature review is to establish a *theoretical* model of the effects of creative idea generation on the design process and the eventual designs produced.	**Model 1** (Figure 2-3) & (Table 2-7)
Chapter 3	**Idea generation and stimuli** – Literature review 2. The purpose of this literature review is to establish a *theoretical* model (model 2) stating how Outer information can stimulate creative idea generation.	**Model 2** (Figure 3-4) & (Table 3-1)
Chapter 4	**Establishing criteria** – Defining influential variables. This is stage 1 of Blessing's methodology. A *theoretical* study was undertaken to identify criteria that may influence the system under study (represented by model 2) and most importantly the success criteria.	**Measurable and success criteria** (sections 4.3& 4.5)
Chapter 5	**Descriptive study 1** – Study of information profiles. This is stage 2 of Blessing's methodology, fulfilled by a 2 part *empirical* study. Firstly, *participation action research*, to understand the system. Then an *observational* information use audit to understand the influences. *Participation action research* • Project management of project Drizzle. • Group design activities of innovation projects. • Familiarity with information management procedures. *Observational research* • Information use audit. • Project profiles information use audit. • Personal profiles information use audit.	**Understand the system** (section 5.2) **Understand influences** (sections 5.4, 5.5 & 5.6)
Chapter 6	**Prescriptive study** – Support tool for creative design This is stage 3 of Blessing's methodology. A *theoretical* study was undertaken establishing a support tool to testing the criteria under study.	**Support tool** (section 6.3)
Chapter 7	**Descriptive study 2** – Stimuli testing. This is the last stage of the blessing methodology. It combines *participation action research* with *case studies* and *protocol analysis*. The purpose being to evaluate both the support tool and the measurable criteria.	**Evaluation of support tool and measurable criteria**

The research approaches used at each stage are in italics.

Figure 1-5 – Customised Research Methodology

2 Creativity in engineering design

Creativity is an integral and essential part of the engineering design process. Without creativity in design there is no potential for innovation, which is where creative ideas are actually implemented (Mumford and Gustafson 1988; Amabile 1996) and transformed into commercial value (Thompson and Lordan 1999; Culley 2002). To emphasise this importance, recent figures were released from the UK treasury concluding that the top innovating companies produce 75% of revenue from products or services that did not exist 5 years ago (Cox 2005)! Within industry, creativity does not necessarily equate to success; however, without it, based on the above observation (Cox 2005), long-term failure is a near certainty.

Having a full understanding of the processes that lead to creative designs over routine designs is of great interest to both individuals and organisations. There has been work (Chapman 2006) to establish design processes to enable more creativity; these process models are often termed "innovation processes". However, to date there are no descriptive innovation process models which are able to make a clear and consistent distinction between a design path leading to a *routine product* and a path leading to a *creative product* (described in section 2.3). By comparing literature from engineering design with creativity literature from cognitive psychology, this chapter highlights some key areas for design researchers to consider. The integration, in some manner, of a creative process as understood in psychology with the overall design process may also help engineers to better utilise creativity tools, methods and techniques from both engineering and psychology.

2.1 Scope of review

This review will attempt to tie together the key areas of creativity theory and engineering design, fundamental to the research conducted within this thesis. The review should provide an understanding of how the research findings will impact both design and creative outputs via both the design and more generic creative processes. In order to conduct this cross disciplinary research, the authors first aimed

to identify areas in both engineering design and cognitive psychology literature that are directly comparable, thus making the knowledge transferable. During this initial scoping, it was realised that in psychology it is common to refer to creativity in reference to the four main areas by which it is researched, namely; the creative 'process', the creative 'product (output)', the creative 'person' and the creative 'environment' (Rhodes 1961; Murdock and Puccio 1993; Basadur *et al.* 2000). In the domain of engineering design it would appear that leading authors categorise design into broadly similar sections using the terms; the design 'problem', the design 'process', the design 'types (output)', the design 'activity' and the design 'organisation/team/personnel' (Pahl and Beitz 1984; Ulrich and Eppinger 1995; Ullman 1997; Cross 2000).

The author previously observed that the engineering design process had many similarities to the creative processes (Howard *et al.* 2007; Howard *et al.* 2008). In addition, it was seen that the characterised 'design outputs' commonly referred to in engineering design literature, show many similarities with the creative product described in psychology research literature. It was therefore decided that the scope of this review would attempt to assess and integrate the different perspectives of the two domains with respect to 'process' related research (section 2.2), and 'product' or 'output' related research (section 2.3). The last two issues considered by the researchers in the psychology area of 'person' and 'environment' are clearly important areas for understanding and supporting creativity, however they are considered outside the scope of this research. In section 2.4 the findings from the previous sections are brought together to link the creative design process to the creative design outputs, thus addressing Objective B.

2.2 The process of creative design

The process by which innovation takes place can be thought of as some form of black box processing large amounts of design related information in order to produce a variety of design outputs, some of which will be 'creative'. Scholars have made attempts to describe and formalise both the engineering design process (section 2.2.1) and the creative process (section 2.2.2), producing generic models that have been

broadly accepted as good representations by both research communities. This review concludes with a comparison between the perspectives from each domain (section 2.2.3) and a suggested descriptive, creative design process that is an integration of the engineering design process and the creative process (section 2.2.4).

The following section summarises the key elements of the different engineering design process models and creative process models. Though several forms of process representation have been published from each domain, what can be thought of as the 'linear style' is by far the most dominant in both cases and therefore has used as the framework on which this review has been based.

2.2.1 The engineering design process

The understanding of the design process is important both to manage the design activity and to aid the improvement of products and the overall efficiency of engineering based companies; it is also the foundation on which a lot of design research is based. It is suggested that understanding this process relative to the creative process will give insight into where and when resources should be focused in order to enhance creative performance and also the resulting 'quality' of the product designed. Thus this section introduces a framework (Table 2-1) which has been generated to define the boundaries of the design process, highlighting the commonalities and differences between the phases it contains. It is based on a detailed analysis of many existing engineering design process models of which 23 are shown in Table 2-1.

There are a number of notable differences between the models, of particular interest are the divergent – convergent models, which include controlled convergence (Pugh 1991) and the double diamond (Design Council 2006) in Table 2-1. These divergent-convergent models differ from the traditional linear style by assuming some form of integrated evaluation and selection of ideas and concepts. This is potentially a useful outlook on design from a creativity perspective, as separating the generation and evaluation periods is considered good practice for both lateral thinking and brainstorming (Osborn 1953).

Another slightly atypical form of representation can be described as a 'knowledge space model'. Here it is assumed that a certain quantity of knowledge must be gained for each phase of the process in order to complete a design. These spaces can be filled in random order or sequence, though there are certain dependencies inbuilt within each design project, i.e. one space cannot gain anymore relevant information until knowledge is gained in another space. A prime example of this type of representation is the C-K theory (Hatchuel and Weil 2003) which describes design as a process of movement between a concept space and a knowledge space. These types of model are probably valid and representative of actual design activities, though it is clear that their high level description makes them less useful to designers. Interestingly, this type of representation did not correspond to the boundaries set by the framework in Table 2-1.

The column headings used in Table 2-1 demonstrate the general agreement of design authors on common -often synonymously named- stages. The six headings comprise the four major design phases; 'analysis of task, 'conceptual design', 'embodiment design' and 'detailed design'. Preceding these four phases is the 'Establishing a Need' phase, where the driver for the design is recognised. It is noticeable that nearly all processes assume a market driven process as apposed to a technology driven process, the exceptions being (Urban and Hauser 1980; Baxter 1995). Following the four major phases is the 'Implementation Phase' which is included by several authors, explaining what happens when the final engineering 'drawings' and instructions are completed. The implementation phase contains only post-design activities and is therefore not the focus of this research.

Models	Establishing a Need Phase	Analysis of Task Phase	Conceptual Design Phase	Embodiment Design Phase	Detailed Design Phase	Implementation Phase
(Booz *et al.*, 1968)	X	New Product Strategy Development	Idea Generation ¦ Screening & Evaluation	Business Analysis ¦ Development ¦ Testing		Commercialisation
(Archer, 1968)	X	Programming ¦ Data collection	Analysis ¦ Synthesis	Development	Communication	X
(Svensson, 1974)	Need	X	Concepts ¦ Verification ¦ Decisions		X	Manufacture
(Wilson, 1980)	Societal Need	Recognize & formalize ¦ FR's & constraints	Ideate and Create	Analyze and/or test	Product, prototype, process	X
(Urban *et al.*, 1980)	Opportunity Identification	Design		Testing		Introduction (Launch) ¦ Life Cycle Management
(VDI-2222, 1982)	X	Planning	Conceptual Design	Embodiment Design	Detail Design	X
(Hubka *et al.*, 1982)	X	X	Conceptual Design	Lay-out Design	Detail Design	X
(Crawford, 1984)	X	Strategic Planning	Concept Generation	Pre-technical Evaluation	Technical Development	Commercialisation
(Pahl *et al.*, 1984)	Task	Clarification of Task	Conceptual Design	Embodiment Design	Detailed Design	X
(French, 1985)	Need	Analysis of Problem	Conceptual Design	Embodiment of Schemes	Detailing	X
(Ray, 1985)	Recognise Problem	Exploration of Problem ¦ Define Problem	Search for Alternative Proposals	Predict Outcome ¦ Test for Feasible Alternatives	Judge Feasible Alternatives ¦ Specify Solution	Implement
(Cooper, 1986)	Ideation	Preliminary Investigation	Detailed Investigation	Development ¦ Testing & Validation	X	Full Production & Market Launch
(Andreasen *et al.*, 1987)	Recognition of Need	Investigation of Need	Product Principle	Product Design	Production Preparation	Execution
(Pugh, 1991)	Market	Specification	Concept Design		Detail Design	Manufacture ¦ Sell
(Hales, 1993)	Idea, Need, Proposal, Brief	Task Clarification	Conceptual Design	Embodiment Design	Detail Design	X
(Baxter, 1995)	Assess innovation opportunity	Possible Products	Possible Concepts	Possible Embodiments	Possible Details	New Product
(Ulrich *et al.*, 1995)	X	Strategic Planning	Concept Development	System-Level Design	Detail Design	Testing & Refinement ¦ Production Ramp-up
(Ullman, 1997)	Identify Needs ¦ Plan for the Design Process	Develop Engineering Specifications	Develop Concept	Develop Product		X
(BS7000, 1997)	Concept	Feasibility	Implementation (or realisation)			Termination
(Black, 1999)	Brief/Concept	Review of 'State of the Art'	Synthesis ¦ Inspiration ¦ Experimentation ¦ Analysis / Reflect	Synthesis ¦ Decisions to constraints	Output	X
(Cross, 2000)	X	Exploration	Generation	Evaluation	Communication	X
(Design Council, 2006)	Discover	Define	Develop		Deliver	X
(Crown Packaging, 2008)	Mission Statement	Market Research	Ideas Phase	Concept Phase	Feasibility Phase	Pre Production

Table 2-1 – Design Process Models

It would appear that these traditional, linear models (Table 2-1) of the design process are extremely effective for teaching novice designers and for managing the design process, e.g. for building stage gates upon. However, it is evident that the engineering design process models are poor with regards to representing creative processes. In Table 2-1 there is one exception in the Fashion and Textile design process proposed by Black (1999), which includes two phases of 'synthesis' and a phase for 'inspiration' both commonly used to describe the creative process (see Table 2-2). It was also recognised that these linear representations are poor for research purposes particularly for mounting creative tools and processes, partly due to the 'idealistic' way by which they are depicted (Parnes and Clements 1986).

In order to address this gap, the authors have related this traditional linear view, to a more complex or sophisticated outlook of the design process as proposed by Gero (2004), relating design to Function, Behaviour and Structure (FBS). It is possible to link the FBS framework (Gero 2004) to 3 of the 4 major design phases of the standard engineering design process as illustrated in Figure 1. Here it is suggested that dealing with the *functions* are set in or are analogous to the analysis of task phase, the *behaviour* of the design is formed in the conceptual design phase and the *structure* is established during the embodiment phase.

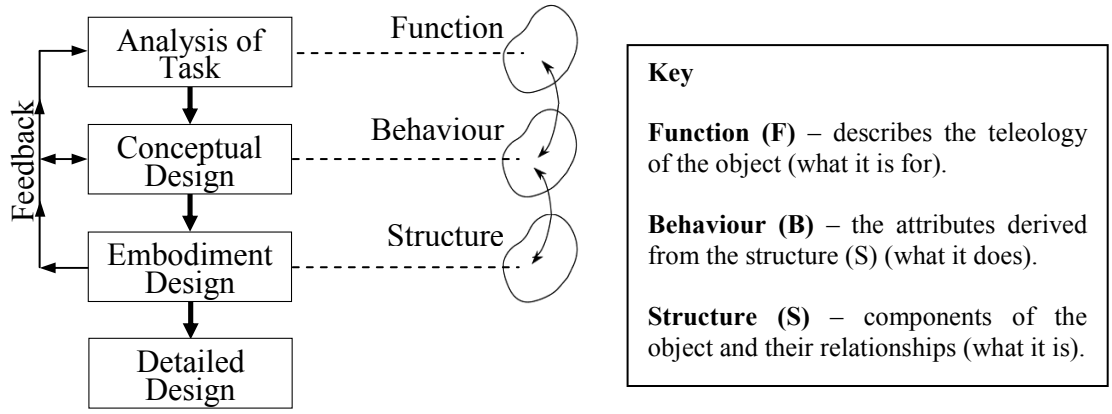


Figure 2-1 – Relationship between FBS (Gero 2004) and the design process

Section 2.2.4 shows how this framework, with its strong links to the usual representations of the design process, can be extremely useful in integrating the engineering design process and the creative process.

2.2.2 The creative process (as described in psychology)

Psychologists can be split into two categories as described by Boden (1990), namely the romantics and non-romantics. The romantics take a more spiritual view of creativity where it is viewed as a mysterious, subconscious process (Barron and Harrington 1981; Plsek 1997). This is still quite a common view of the creative process; however analysis of the literature has shown that it is of little help to research in engineering design. However, the non-romantic view, taking an interpretable and modelable view of creativity, has a number of very interesting aspects which will be used in this work. Thus the following section will take the reader through the different descriptions of several non-romantic views on creativity. A comparative summary of the process models can be found in Table 2-2, from which conclusions will be drawn.

Similar to the design process the representation of the creative process takes several forms within the literature. But interestingly even in the psychology domain, the form is predominantly described as a linear sequence of steps or stages. Earlier descriptions of the creative process, coined by Shneiderman (2000) as 'inspirationalist' views from the early 20th century, are perhaps the most valuable to engineering design. One of the older process models is the four-stage process offered by Wallas (1926) which although it remains the most well recognised of all creative process models, though his stages of preparation, incubation, illumination and verification, has some critics (Thompson and Lordan 2001).

This approach suggests the sudden emergence of an idea, which is now often deemed somewhat outdated. More recent descriptions, coined by Shneiderman (2000) as 'structuralists', attempt to offer an explanation to emergence, describing conscious idea-generation as the deliberate connection of matrices of thought (Koestler 1964). This process is likened to belief by Amabile (1983) -where new ideas are generated through the combination of two or more old, existing ideas- and is typical of a structuralist view. Both of these views on idea generation stem from Aristotle's rules of association, though it is noted that neither can distinguish between a process leading to a creative idea and one producing a routine idea.

As with the engineering design process there are instances of the divergent-convergent style representations of the creative process from psychology literature. It was possible to position some of these processes within Table 2-2 as they were deemed to be hybrids incorporating divergent-convergent stages into the more common linear process (Guilford 1957; Jones 1970; Basadur *et al.* 2000). Nevertheless this section will concentrate on the linear-style processes which dominate the representations in Table 2-2. In constructing this table the 19 process models from the literature were analysed in detail and the various phases were compared and then grouped. It was then possible to create 4 major groupings, which arguably represent the major phases of a creative process as seen by the researchers in the psychology domain. Broadly put these phases are analysis, generation, evaluation and communication / implementation.

Analysis of the table shows that over time, there has been a general shift from describing the creative process as subconscious cognitive phases (Helmholtz 1826; Wallas 1926; Kris 1952) to activity-based stages (Jones 1970; Parnes 1981; Amabile 1983). It therefore must be noted that due to this shift, phases -particularly in the generation column- are not precisely synonymous. For the purpose of this research the authors argue that the creative process ends with the evaluation stage as the communication/implementation phase should be deemed a design activity. Thus the generic creative process model used for this research: contains the three stages of analysis, generation and evaluation.

Models	Analysis Phase				Generation Phase			Evaluation Phase	Communication / Implementation Phase		
(Helmholtz 1826)	Saturation				Incubation	Illumination		X	X		
(Dewey 1910)	A felt difficulty	Definition and location of difficulty			Develop some possible solutions			Implications of solutions through reasoning	Experience collaboration of conjectural solution		
(Wallas 1926)	Preparation				Incubation	Illumination		Verification	X		
(Kris 1952)	X				Inspiration			Elaboration	Communication		
(Polya 1957)	Understanding the Problem	Devising a Plan			Carrying out the Plan			Looking Back	X		
(Guilford 1957)	X				Divergence			Convergence	X		
(Buhl 1960)	Recognition	Definition	Preparation	Analysis	Synthesis			Evaluation	Presentation		
(Osborn 1963)	Fact-finding				Idea-finding			Solution-finding	X		
(Parnes 1967)	Problem, challenge, opportunity	Fact-finding	Problem-finding		Idea-finding			Solution-finding	Acceptance-finding	Action	
(Jones 1970)	Divergent				Transformation			Convergent	X		
	Search for Data	Understand the Problem			Pattern finding	Flashes of Insight		Judgement			
(Stein 1974)	X				Hypothesis formulation			Hypothesis testing	Communication of results		
(Parnes 1981)	Mess Finding	Fact-finding	Problem-finding		Idea-finding			Solution-finding	Acceptance-finding		
(Amabile 1983)	Problem or task presentation	Preparation			Response generation			Response Validation	Outcome		
(Barron and Harrington 1981)	X				Conception	Gestation	Parturition	X	Bring up the Baby		
(Isaksen *et al.* 1994)	Constructing Opportunities	Exploring Data	Framing Problem		Generating Ideas			Developing Solutions	Building Acceptance	Appraising Tasks	Designing Process
(Couger *et al.* 1993)	Opportunity, Delineation, Problem Definition	Compiling Information			Generating Ideas			Evaluating, Prioritising Ideas	Developing an Implementation Plan		
(Shneiderman 2000)	Collect				Create				Donate (Communicate)		
	Relate										
(Basadur *et al.* 2000)	Problem Finding	Fact Finding	Problem Defn.		Idea Finding			Evaluate and Select	Plan	Acceptance	Action
	Diverge – Converge at each stage										
(Kryssanov *et al.* 2001)	Functional Requirements	Structural Requirements			Functional Solutions	Analogies, Metaphors		Reinterpretation	X		

Table 2-2 – Creative Process Models

2.2.3 Comparison between the 'processes' of design and creativity

The previous sections have created the summary Table 2-1 and Table 2-2, which contain the major elements that have been identified by authors in the engineering design process area (23 in total) and the work on the creative process from the psychology perspective (19 in total). Here the various views are compared to understand basis for the integrated model that is presented in section 2.4. One notable similarity between the processes is the need for information and its analysis and understanding at the beginning of the processes ('analysis of task phase' and 'analysis phase'). This phase is almost identical in both processes and is therefore a central component of the proposed integrated process.

The main differences arise when assessing the conceptual design phase and the embodiment design phase. It would appear that both of these phases contain all three phases of the creative process, namely analysis, generation and evaluation. The creative process can therefore be seen as a sub-process to the engineering design process and is continually cycled through the first three stages of the design process as shown in Figure 2-2.

Following the embodiment stage is the detailed design phase when engineering designers produce formal communication documents for manufacture/ implementation. In descriptions of the creative process this stage involves the less formal externalising or sharing of the idea and is judged by many to be in addition to the creative process. An earlier more simple description of how the two processes may interact can be seen in Figure 2-2.

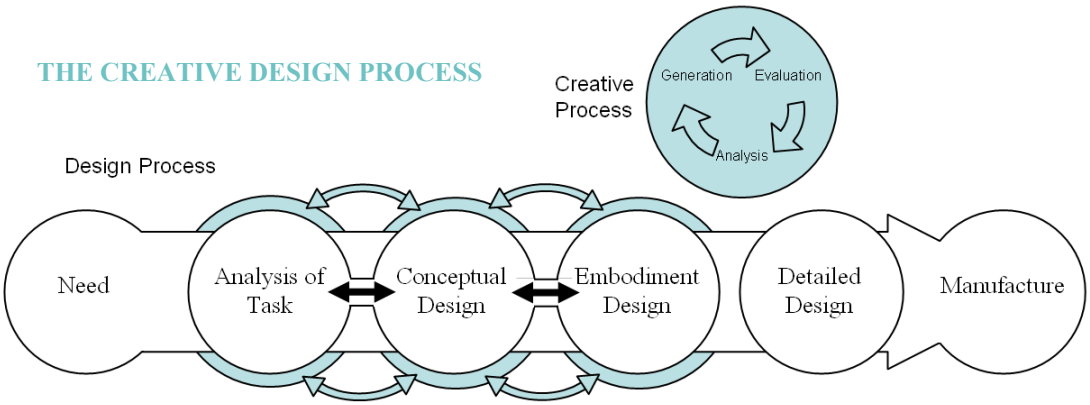


Figure 2-2 – The simplistic creative design process

In more recent research (Basadur *et al.* 2000; Kryssanov *et al.* 2001) psychologists have moved from thinking of the creative process as a cognitive process, to a more activity-based one, more analogous to the design process. In doing this, many recent creative process models could, interestingly, be interpreted as extremely generic design process models. This is an interesting convergence of ideas for engineering design authors who have promoted similar ideas for some time (Archer 1968; Booz *et al.* 1968). Conversely, the linear engineering design process has remained relatively unchanged, the major developments really only being the inclusion of more feedback loops and the acknowledgment that the design process in practice is more erratic than most representations suggest (Parnes and Clements 1986; Bucciarelli 1994).

2.2.4 Integrated model of the 'process' of creative design

The consensus view of creative processes (analysis, generation and evaluation) will now be mapped onto a view of the design process. In doing this specific creativity tools can be created and or positioned for their effective use in the design process. For reasons discussed in section 2.2.1 the authors have adopted the function, behaviour, structure (FBS) model of design (Gero 2004).

Figure 2-3 shows an enhanced version of the FBS model. In grey are the 8 different design operations proposed by Gero (2004) (described in Table 2-3). This splits the behaviour components into expected behaviour (Be) for generative steps and the behaviour derived from the structure (Bs) for evaluative steps. The solid lines

represent the different design operations (transformations and comparisons) of the FBS approach which can be found listed in Table 2-3.

Mapped onto this FBS model are the 3 creative process elements, shown in black, with the important information transfers shown as dotted lines. Table 2-3 is also then extended to show how each design operation relates to the stages of the creative process. This gives a view of the creative process from the domain of psychology compared to the view of the design process from the domain of engineering design. The analysis phase is considered central to this model representing the continual interpretation and use of information which is seen as essential to the creative process. It is believed by the authors that the addition of this 'analysis' component is an important addition to the model. The previous FBS framework (Gero 2004) did not take into account the continual growth and manipulation of design information throughout the design process, which was previously encapsulated by the 'analysis of task' phase and the feedback loops.

Figure 2-3 along with Table 2-3 shows that transformations 1,2,6,7 & 8 are design activities directly related to the generation stage of the creative process. Transformations 3 and 4 are directly linked to the evaluation phase of the creative process. Transformation 5 is deemed as routine design and therefore does not feature in the creative process, though it may require great skill.

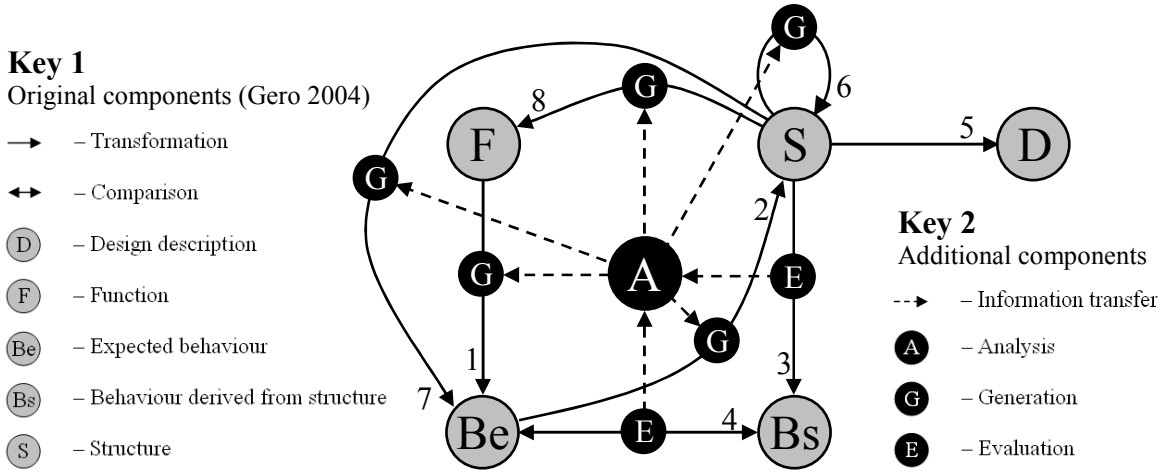


Figure 2-3 – Integrated Creative-Design Process Model

Design Operation from (Figure 2.3)	Descriptions of the activities that make up design (Gero, 2004)	Nature of the activities in creative process terms
Formulation (process 1)	Transforms the design requirements, expressed in function (F), into behaviour (Be) that is expected to enable this function.	Generation
Synthesis (process 2)	Transforms the expected behaviour (Be) into a solution structure (S) that is intended to exhibit this desired behaviour.	Generation
Analysis (process 3)	Derives the 'actual' behaviour (Bs) from the synthesised structure (S).	Evaluation
Evaluation (process 4)	Compares the behaviour derived from structure (Bs) with the expected behaviour to prepare the decision if the design solution is to be accepted.	Evaluation
Documentation (process 5)	Produces the design description (D) for constructing or manufacturing the product.	N/A
Reformulation type 1 (process 6)	Addresses changes in the design state space in terms of *structure* variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.	Generation
Reformulation type 2 (process 7)	Addresses changes in the design state space in terms of *behaviour* variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.	Generation
Reformulation type 3 (process 8)	Addresses changes in the design state space in terms of *function* variables or ranges of values for them if the actual behaviour is evaluated to be unsatisfactory.	Generation

Table 2-3 – The FBS Framework Key (Gero 2004)

The above model (Figure 2-3) is a representation linking both the creative process and the engineering design process in a novel and useful manner. In particular it shows the separate ways by which it is possible to assess the generation phases of the creative process in terms of engineering design. This will enable researchers to categorise and focus creative idea generation tools to suit the particular stage or activity that the designer is actually undertaking.

Although considered good representation by the authors, this model, along with all the other processes reviewed in both domains, shows no link to what is referred to as the creative design output (section 2.3). It therefore does not make any differentiation between a process leading to a creative design over one leading to a routine design. Thus the creative output will be discussed and developed in chapter 3 with the concluding links between the two proposed in section 2.4.

2.3 The creative design output

A clear definition of, or a metric for a creative design output consisting of measurable elements, would enable researchers to gauge the effectiveness of any new creativity tools or methods proposed. In this section it will be shown that the classification of the 'design output' (section 2.3.1) in the domain of engineering design -often referred to as design types- closely relates to the research performed by psychologists involving 'creative outputs' (section 2.3.2). A comparison between the two different views is produced (section 2.3.3) followed by a tabulated model (Table 2-6) describing how they intersect with respect to the design process. This will help to produce a composite definition of a creative design output in section 2.3.4.

2.3.1 Engineering design outputs

Throughout design research, categorising the different outputs of design has proven to be useful for both analysis and the construction of tools, methods and techniques. The different output types are generally related to a design output's distance from the current paradigm, and are often independent of the discipline or domain. Numerous researchers from the field of engineering design have identified different design outputs, for example the well referenced and simple classification system offered by Pahl and Beitz (1984) detailing three primary classes of design:

Original Design: An original solution principle for a system with the same, a similar or a new task.
Adaptive Design: Adapting a known solution principle to satisfy a new or changed task.
Variant Design: Varying the certain aspects of the system leaving the function and solution principle unchanged.

As with the above scheme, many of the output categories proposed by the various authors clearly differ in the levels of creativity, or at least the novelty, expected to be produced. Table 2-4 shows how the various authors categorise the different design outputs, where the columns are organised to exhibit the synonymous or closely related design types. The columns are ordered from left to right, *decreasing* in the

levels creativity expected for each design type. Headings were chosen to describe the level at which each design type has the *most noticeable* effect.

It would appear that by Pahl and Beitz's (1984) definition, the differing design types are clearly related to the design process and thus to the FBS model (Gero 2004), where 'original' design is assigned to an original 'behaviour' and 'adaptive' design to original 'function'. The authors consider these design type classifications to work over the spectrum of systems levels, for example on a 'systems' level a product may be of type 'variant' however it may be adaptive and original at 'component' and 'sub-component' levels. The knowledge of this relationship will add to the composite definition described at the end of this section (2.3.4).

Level of effect	Most original → Least original			
	Behavioural	Functional	Structural	Incremental
(Matousek 1963)	New	Adaptive	X	Development
(Gasson 1973)	Original	Extensional	Transitional	X
(Pahl and Beitz 1984)	Original	Adaptive	Variant	X
(Black 1989)	Innovative	Adaptive	Variant	Order
(Henderson 1990)	Radical	X	Modular / Architectural	Incremental
(Culverhouse 1993)	Innovative	Strategic	Variant	Repeat Order
(Ullman 1997)	Original	Redesign	Configuration	Selection
(Gero 2001)	Creative	Innovative	X	Routine

Table 2-4 – Design Output Categories

It was observed that several of the authors also view these design outputs from the initial problem or activity perspective (Ullman 1997). In which case, it is thought that the designers begin their design work with a notion that the eventual product will be either; innovative, adaptive, variant or to order (Table 2-4) and thus perform the appropriate activity (design type).

While these different design types have the essence of varying levels of creativity, within their definitions they do not explicitly distinguish what is creative/inventive design from what is routine design. Ottosson (2001) states that for a product to be new, technically it must have 60% of new or redesigned parts and from a marketing

point of view, it needs to be considered new to the market. In engineering design there is one accepted judgment of inventiveness, and it relates to the designs patentability. In order to become an invention or be granted a patent a design must fulfil the following criteria (The Patent Office 2007):

Be new: The invention must never have been made public in any way, anywhere in the world, before the date on which an application for a patent is filed.
Be capable of industrial application: An invention must be capable of being made or used in some kind of industry. This means that the invention must take the practical form of an apparatus or device, a product such as some new material or substance or an industrial process or method of operation.
Involve an inventive step: An invention involves an inventive step if, when compared with what is already known, it would not be obvious to someone with a good knowledge and experience of the subject.

Interestingly the first two criteria resemble elements that are used by psychologists to characterise a creative output (i.e. Originality and Appropriateness see section 2.3.2). The term Un-Obvious as the third criterion provides a revised definition of a creative output presented previously (Howard *et al.* 2006), see Table 2-5.

2.3.2 Creative output

When defining the creative output it is important to note that an output is considered to be a single idea, comprising of an association of two chunks of information (Howard *et al.* 2006). Though this is often termed as the creative product in psychology literature it can cause confusion between the domains, as engineers think of a product as a finished artefact, usually of commercial value.

In the romantic view, the creative output is considered something magical, astonishing (Boden 1990) or godlike (Goldenberg and Mazursky 2002), however, most scientific literature describes a creative output as something both original and appropriate. Table 2-5 displays the various definitions of the non romantic views of the creative output. It can be seen that the two main elements of Originality and Appropriateness or their synonyms are present in all definitions.

Due to the broad nature of this definition, it is common for authors to add some form of third element to their definitions in order to focus on the aspect of creativity their particular research deals with (see Table 2-5). For the purpose of this study the Un-Obviousness (Goldenberg and Mazursky 2002; Lopez and Vidal 2006) is included as the third element. The idea came partly from looking at the patenting criteria, but also because some design tasks are so novel that any proposed solution may be judge Original. However, if given the same task a high proportion of designers and competitors were to produce the same Original idea relatively quickly, should it really be deemed creative? It is therefore required to emphasise the use of Un-Obviously related information as a function of time.

Definitions	Originality			Appropriateness						Third Element								
	Novel	Original	New	Appropriate	Useful	Purposeful	Value	Meaningful	Tenable	Satisfying	Unobvious	Adaptive	Leap	Change	Unexpected	Communicated	Transformation	Condension	Resourceful
(Jackson and Messick 1965)	X			X													X	X	
(Stein 1974)	X				X				X	X			X	X					
(MacKinnon 1975)	X									X		X				X			
(Rothenberg and Hausman 1976)			X				X									X			
(Simon 1979)	X						X												
(Amabile 1983)	X			X															
(Sternberg 1988)	X				X														
(Lumsdaine and Lumsdaine 1995)			X					X											
(Gero 1996)			X				X								X				
(Marakas and Elam 1997)	X				X														
(Thompson and Lordan 1999)			X		X														
(Warr and O'Neill 2005)	X			X															
(Chakrabarti 2006)	X					X													X
(Howard, *et al.* 2006)		X		X							X								
(Lopez and Vidal 2006)	X					X					X								

Table 2-5 – Creative Output Definition

It is often easy to gauge how Appropriate an idea is through simple testing and evaluation, – if it works or fits the specification, it is Appropriate. Though researchers from other domains emphasise, there is no right or wrong answer: 'good' rather than 'correct'; 'poor', rather than 'wrong' (Warr 2007). Other elements such

as Originality are less robust in definition. Boden (1990) distinguishes between an idea that is original to the beholder (P-Creative) and an idea that is original historically (H-Creative).

A good example of this differentiation in reality is in the gyroscope patent. In 1898 an original patent for the gyroscope was finalised, unbeknown that its details could be found in Leonardo da Vinci's notebook dating back to the sixteenth century. It could therefore be argued that the gyroscope patent was P-Creative but not H-Creative. These two types of originality really divide the domains of engineering and cognitive psychology. Engineers are far more concerned with H type originality as it enables intellectual property rights such as a patent (see section 2.3.1); psychologists are much more concerned with P type originality, to analyse the creative processes of individuals.

With regards to assessing what is creative in a specific case (i.e. Original, Appropriate and Un-Obvious) there are few people who can make this judgment. Amabile (1983) states that there are few objective methods of evaluating the creativity of a product, and for the most part, evaluation is done by applying subjective judgements. This is complemented by Shalley et al. (2004) who believe that only a field expert or line manager can judge whether these elements exist in a particular idea, thus determining whether it is creative or not.

2.3.3 Comparison between the 'outputs' of design and creativity

The most noticeable difference between the output related definitions from the two domains is in the size and complexity of the output being defined. In engineering design the outputs being defined (the different design types) are complete products, components and solutions often produced by complete teams of designers. In the case of psychology research the outputs to be defined tend to be 'single ideas' produced by individuals.

In terms of the characteristics that define what is creative from what is routine psychologists define the creative output with markedly *similar criteria* to that required for an invention or a patentable design. However, the engineering design

community appears to go a step further, breaking these designs further into different design types, relating to how creative or original particular aspects of each design are. A common theme emerged from the literature defining the different design types. This tended to distinguish between the levels of creativity exhibited at functional, behavioural and structural levels. This trend is built-in to the composite definition in the following section.

2.3.4 Composite definition of the 'output' of creative design

In order to form a composite definition of the creative design output and thus gain better understanding of the different definitions, it is useful to consider both views alongside the stages of the design process. Table 2-6 has been generated using the standardised headings of the design process from section 2.2.1 along with its relationship to function, behaviour and structure (described by Figure 2-1). Then taking Pahl and Beitz's (1984) definitions of design types as a standard example it is possible to see how the different design outputs can be defined by the stage of the design process at which the major creative output occurs.

		Stage of Design Process			
		Analysis of Task (Function)	Conceptual Design (Behaviour)	Embodiment Design (Structure)	Detailed Design
Design Outputs	Original		Creative Output		
	Adaptive	Creative Output			
	Variant			Creative Output	
	Routine				

Table 2-6 – Creative Output occurrence in Design Process for Design Types

Table 2-6 indicates that if no creative output is produced the design will be routine at best. The three main design types all contain creative outputs, and can be differentiated between by the FBS relative position in which this creative output occurs. For example, an adaptive design output would expect to contain the predominant creative output at a functional level (associated to the analysis of task stage). It is obvious from Table 2-6 that the different design outputs are defined from

an engineering/technology perspective, defining an original output to be related to behaviour and thus the conceptual design phase. A user orientated classification may see original design being related to function and thus the analysis of task phase (more marketing than engineering) and an architectural orientated classification may see original design being related to its structure.

The following definitions are constructed in reflection of both the definitions of design outputs (section 2.3.1) and of creative outputs (section 2.3.2).

A creative output: An idea that is original, Appropriate and Un-Obvious.

A creative design output: A design output containing at least one creative output at the systems level under study.

A routine design output: A design output containing no creative output at that particular systems level.

In addition consider the following definitions of the three types of creative design outputs:

Original design output: A design output in which there is a creative output at the behavioural level.

Adaptive design output: A design output in which there is a creative output at the functional level.

Variant design output: A design output in which there is a creative output at the structural level.

The above definitions could be useful for categorising products and product features for research purposes and legal property (Intellectual property) issues. These definitions are now used within the next section to link the creative design process to the creative design output.

2.4 Link between the creative design process and product

Though fundamental to design research, the process and output of creative design has yet to be linked theoretically or empirically. The following section will propose a simple model consolidating at least half a century's worth of work from both cognitive psychology and engineering design. The model links the integrated creative design process (section 2.2) to the composite definition of the creative design output (section 2.3), clearly fulfilling Objective B.

It became evident that the generation phase of the creative process has the greatest bearing on the different design outputs (sections 2.2 & 2.3). If any design operation involves a creative generation phase (an Original, Appropriate and Un-Obvious idea) then one of the three creative design outputs will be produced. In the case where several creative generation phases occur at one of the systems levels of the design then it is a hybrid of the design types. It is important to realise that a routine design has no creative generation phases. Table 2-7 identifies 5 design operations that if performed creatively will lead to the various creative design outputs. The implications of this link between the creative design process and the outputs allow us to position creative design tools respective to the design operation being performed.

Design Operations (Figure 2-3)	Nature of the activities in creative process terms	Resultant creative design output
Formulation (process 1)	generation	Original
Synthesis (process 2)	generation	Variant
Analysis (process 3)	evaluation	N/A
Evaluation (process 4)	evaluation	N/A
Documentation (process 5)	N/A	N/A
Reformulation type 1 (process 6)	generation	Variant
Reformulation type 2 (process 7)	generation	Original
Reformulation type 3 (process 8)	generation	Adaptive

Table 2-7 – Link between creative design process steps and the creative output

With these mechanisms now realised, research must be conducted a lower level of granularity to understand what detailed mechanisms lead to Original, Appropriate

and Un-Obvious ideas being produced during the generation phases. In some preliminary theoretical work (Howard *et al.* 2006) the authors proposed and tested whether an idea is creative or routine is dependent on the information inputs to the process. It is suggested that the 'Apparentness' and 'Relevance' of the information is key to this creative generation process and will be investigated in following chapters.

2.5 Conclusions

Having reviewed literature from the domains of engineering design and psychology, a creative design process (Figure 2-3) is proposed as an integration between the engineering design process and the creative process established from cognitive psychology. Whilst acknowledging that design processes observed in practice are more erratic than most representations suggest, it is argued that understanding the linkages in the overall process will help engineers to better utilise creativity tools, methods and techniques. Insight into this process may also reveal where and when resources should be focused in order to enhance creative performance and the quality of the product designed.

A composite definition of a creative design output is also presented, taking elements from the different design types proposed in engineering design and the creative outputs proposed in psychology. A clear definition of a creative design output consisting of measurable elements (Originality, Appropriateness, Un-Obviousness) will enable researchers to gauge the effectiveness of any new creativity tools and methods proposed (section 6.2). The integrated process and composite definition are linked within Table 2-7 stating the process routes leading to the different design outputs.

This deeper understanding will enable more effective tools to be created and utilised, helping the engineering designer to produce more Original ideas or to reach them more quickly. It has been shown (section 2.2) that information has an important, but not fully understood role, to further the support of creative activities it is clear that studies must be conducted with engineering designers to audit existing information types and sources used as design inputs (see chapter 5). In addition, descriptive

studies should be conducted with engineering designers to test the impact of the different types of information on creative inspiration at different stages of the design process (see chapter 7).

This chapter has identified that it is the position of the creative and routine outputs (of the creative process) relative to the engineering design process that distinguished the design types produced. Though the theory states that the creative and routine outputs are formed within the generation phase of the creative process, the mechanisms by which they are actually formed are not fully understood and will be reviewed and investigated in the following chapter.

3 *Idea generation and stimuli*

One of the under researched areas associated with creativity is the role that information plays in enhancing or even inhibiting creative design activities. The following chapter is a more focused literature review concentrating on this aspect of idea generation and the effect of creative Stimuli. In an advancement of the previous chapter, understanding creative idea generation and creative stimulation further explains the process leading to the different creative design outputs.

This chapter first assesses the creative process developed in section 2.2.2 in terms of the information inputs. In the first phase of analysis (section 3.1) a categorisation scheme is proposed describing the different types of information inputs into idea generation. This is followed by the generation phase (section 3.2) where the key process of association is described showing how such information inputs are used to form an idea. The evaluation phase is not dealt with as it occurs after the idea is generated (see Figure 2-3). However, the stage is essential to design, where an idea is assessed for its Appropriateness; the resulting information is introduced to future analysis phases.

In section 3.3 a mechanism is proposed using the information inputs and the process of association to distinguish between routine idea generation and creative idea generation, thus addressing Objective C. This will highlight how creative Stimuli, a form of information, are used to create an idea. The following sections will then review relevant research regarding both idea generation and the effects of creative Stimuli (section 3.4) and the use of design entities (section 3.5).

3.1 Analysis

Analysis is the first stage of the creative process and essentially involves the collecting and relating of information (Shneiderman 2000). All relevant information and knowledge inputs including those incurred through previous experiences and evaluation phases are added for the purpose of problem definition or task clarification. In terms of information, this is the only phase of the process that develops, increasing in size as the designer progresses through the design process. The author proposes that the creative output is dependant on the information collected and accessed at this stage. It is thus important to understand the types of information inputs involved, how they are used, and where they are stored.

3.1.1 Information storage

The way by which information is stored, accessed and reused is of great importance when understanding the cognitive process of idea generation. While storing information externally can seem straight forward, the internal storage is far more complex and causes confusion between terminology such as data, information and knowledge. Hicks (2002) defines information as data with context. To turn information into knowledge there is some form of knowledge process, which is the process of understanding the information. The product of this is a knowledge element, which is restructured and stored as information.

The understanding process is key to the storage and reuse of knowledge. This understanding is performed relative to other information stored, and allows a network to be formed linking the new information to other knowledge elements via a web of attributes. For engineering design, these attributes are in the form of function, behaviour and structure (Benami and Jin 2002; Gero and Kannengiesser 2003) and are stored as information themselves. Linking information in this way allows designers to form ‘chunks’ (Miller 1994), which are meaningful groupings of information compressed to enable more space in the working memory. While a personal trait of domain experts is their ability to form these chunks of information, it also explains why experts often do not posses the child-like or novice-like creativity.

3.1.2 Information inputs

Idea generation and therefore creativity cannot begin without the availability of knowledge and information. This information is used to improve understanding of the problem through descriptive associations, and to stimulate associations and ideas through solution associations (see section 3.2.2).

The types of information used have been categorised against two criteria "Apparent-Relevance" and "Location". Apparent-Relevance is a criterion extremely similar to the two attributes of Un-Obviousness and Appropriateness as defined in section 2.3.2 for the creative output. It must be noted these are subtly different; Relevance refers to how Relevant information is to a task, Appropriateness refers to how appropriate a generated idea is to a task. Location refers to the position of the information, Inner being cognitively stored, Outer being experienced from outside the human body.

		Location	
		Inner	Outer
Apparent - Relevance	High	Working Memory	Task Information
	Low	Long Term Memory	Surrounding Information

Table 3-1 – Information Categories

3.1.3 Inner information

Inner information sources are predominantly stored in two Locations, the long term memory considered similar to a computer storage hard drive, and the working memory considered similar to the RAM (Random Access Memory) of a computer. It is in the working memory that the information is processed, creating associations and ideas. During design tasks, Apparently-Relevant information is drawn from the long term memory to the working memory to form meaningful associations. It has been argued (Engle *et al.* 1999) as a kind of conceptual space where the working memory capacity is the ability to keep a representation alive. The working memory will therefore be rich in Relevant information, where as the long term memory will consist of information that is both irRelevant and '(un)Apparently' Relevant. The working memory does however have limited capacity said to be between 5 and 9

chunks (Miller 1994), this can be somewhat alleviated by transferring information into long-term memory or externalising the information (e.g. sketching it down on paper).

3.1.4 Outer information

This is all information Outer to the designer. Social interaction between the designer and colleagues is viewed as one directional with this approach. The colleague is simply considered as dynamic information. This has been done to allow the author to focus on the information input and individual creativity rather than social- or team-creativity. The task information is considered highly Relevant to the design task. This will be the information stored in the project files as requirements, briefs, specifications, constraints etc. The surrounding information is considered largely irrelevant or Un-Apparently Relevant, encompassing background noise, scenery, smell and other sensory forms of input. This information is usually separated from the design task by either space or time. Spatially this information is predominantly in the peripheral vision. When the information is in focus, it is often differentiated by time from the concentration of the task (e.g. day dreaming, relaxing or working on other projects). The authors propose that it is only when this Un-Apparently-Relevant information comes into focus, whilst concentrating on the task, that a creative idea can be formed.

3.2 Generation

The generation phase is the most import stage with respect to the production of creative design outputs (see section 2.3.4). In the previous chapter the importance of the generation phase was realised when positioned relative to the design process. In this section the generation phase will be described with reference to the information inputs. The stage is separated out from an inspirationalist (Shneiderman 2000) viewpoint, with sub-phases such as Wallas's (1926) incubation (section 3.2.1) and illumination (section 3.2.2) which details the vital process of association.

3.2.1 Incubation

This is a relatively unexplained cognitive process where the problem information from the preparation stage is put aside for an unknown period of time until an idea or a solution suddenly emerges. It is proposed that incubation can aid idea generation in two possible ways; these are termed stimulative incubation and suppresative incubation. Stimulative incubation is where the brain is simply waiting to be stimulated or subjected to the right piece of stimulating information. Suppresative incubation is where the brain is waiting for creative suppression (mental blocks or fixation) to be removed, enabling new and previously unobtainable connections to be made. In reality it is probable that both types of incubation can occur.

The authors hypothesise that the addition of this phase could be what distinguishes a creative idea from a routine idea. Where routine ideas can be instantly formed from the freely available Relevant information, incubation is required to retrieve the Un-Apparently Relevant information and thus create original associations as creative ideas. It is therefore proposed that the incubation period is in fact not determined by the length of time, but by the type of information that the designer is subjected to during this period. If this claim is supported, research into this area may lead to shortened incubation periods providing value to design activities in an industrial context.

3.2.2 Illumination

This is a complex and instantaneous phase where an association is made between two bits of information, commonly called the ‘Ah ha’ or ‘Eureka’ moment. The full explanation of illumination is far beyond the realms of this research; however, the information considered during this phase can be assessed by studying associations, the primary aspect of illumination. An association is the result of an information processing activity using two or more chunks of information (Howard *et al.* 2006). It is the most recognised process leading to idea generation. The great Albert Einstein once said:

“the secret to creativity is knowing how to hide your sources”

This is a very insightful statement complementing associationist views. In essence this means that a complicated, 'creative' idea can be broken down into its simple associated parts.

Aristotle stated three distinct rules of association:

Similarity: some 'sameness' of properties in two physical things or situations.
Contrast: an association because of a difference in properties.
Contiguity: associating two objects or ideas by virtue of their physical placement.

Pugh (1991) also suggests types of association used to aid idea generation such as analogy, attributes, inversion and combination. Metaphors are also common form of association used in design and regularly in the arts. In simple terms, an association is recognising some relationship between two chunks of information in the working memory. The more abstract the association is, the more creative the result is deemed to be. Cartoons and joke telling are good example of this. When the punch-line of a joke is too obvious and the audience can see it coming from a mile off it is because the association is not abstract enough. If too abstract the joke may lose it Appropriateness and become technically not a joke. It is therefore association giving surprise that determines the creativity of a joke or cartoon (Mishon 2003).

Some ideas in problem solving and design are complex and the associations are hard to pinpoint. The TRIZ philosophy (Altshuller 1999) states that there are no complex problems but simple problems stuck together, likewise, there are no complex associations or ideas just simple ones stuck together. Some more abstract associations are harder to create or recognise. For example, the association drawn from emotional response (behaviour) of two design entities is not as easy to recognise as between the appearance (structure) of two objects.

The authors have separated these types of associations into two groups, a Descriptive Association (analogy, metaphor, simile etc.) and a Solution Association. Both approaches are described below and illustrated in Figure 3-1 and Figure 3-2.

Descriptive Association: This is an essential approach for turning information into knowledge. In order to understand or comprehend something, information must be related to, other chunks of information. A descriptive association is when another piece of information is introduced (the descriptor) to further describe and understand the problem or solution. It could be the case that all evaluation and understanding is formed from descriptive associations. As an example, consider the virtual 'desktop'. Here the problem is, a user requires quick access to tools and current files, the solution is making the backdrop to the operating system a file space, and the descriptor is the a physical 'desktop' as the behaviour of a physical desktop and the virtual desktop are associated Figure 3-1.

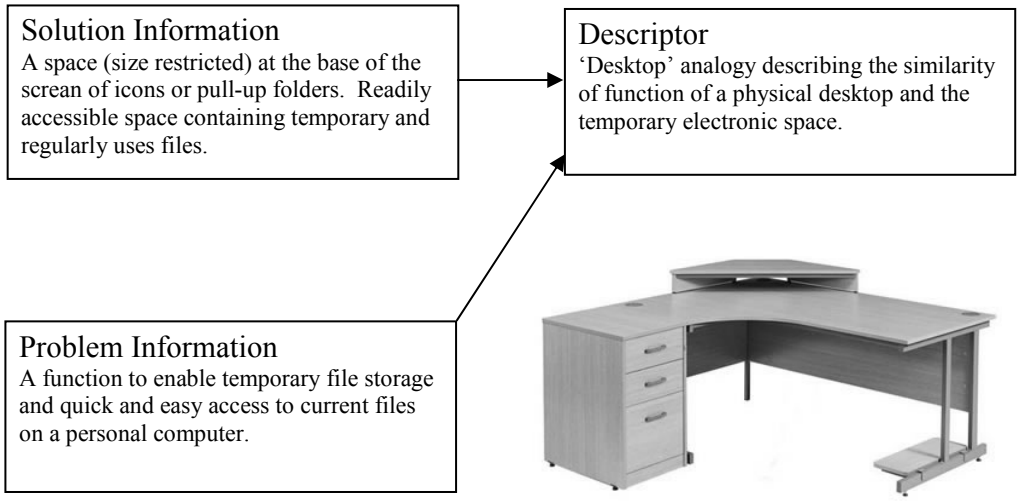


Figure 3-1 – Descriptive Association (www.desk-warhouse.co.uk)

Solution Association: This is where a chunk of information is associated during problem solving. Rather than describing a solution to a problem, in a solution association the descriptor is used during problem solving to prompt a solution. As an example consider Marc Brunel tunnelling shield (Figure 3-2).

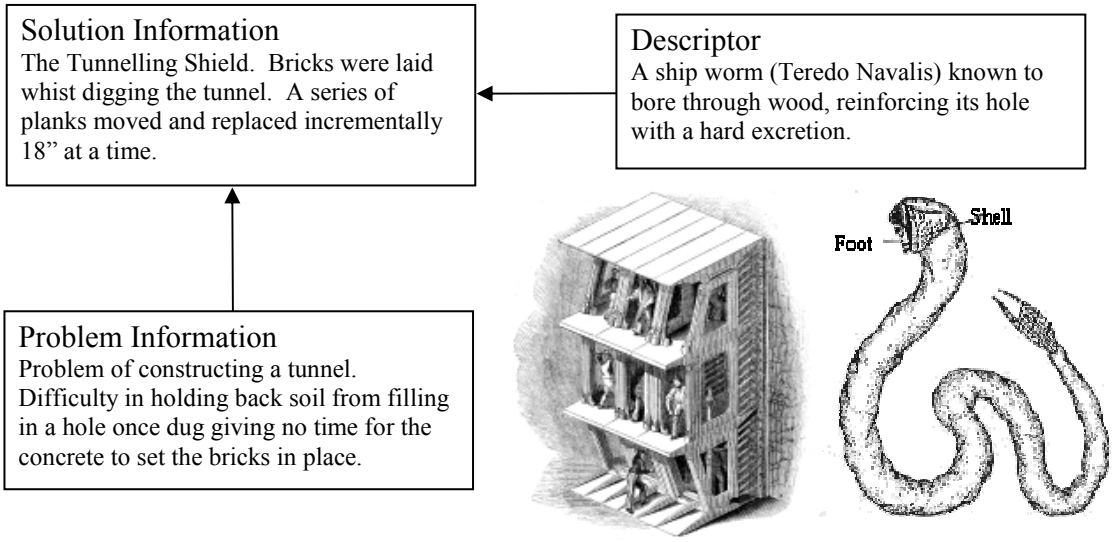


Figure 3-2 – Solution Association (www.icons.org.uk; www.manandmollusc.net)

3.3 Creative idea formulation

In the previous sections we have explored the types of information involved during the analysis phases (section 3.1) and the process of association which can convert chunks of information into ideas (section 3.2). In this section a cognitive mechanism is proposed tying the information from the analysis phase to idea generation (through analogy), thus satisfying Objective C. This is an alternative view of the idea generation process and unlike any other referenced, differentiates between *routine* idea generation and *creative* idea generation.

3.3.1 Routine idea generation

Routine idea generation refers to ideas that are Appropriate, and sometimes Original, but obvious to an expert in the domain. This type of idea generation can be forced, requires no incubation phase and depends on concentration levels and previous knowledge. Figure 3-3 is a proposal to show how the task information (section 3.1.2) is analysed and the Apparently-Relevant chunks of information are drawn into the working memory. These chunks of information are then associated with the task information and other chunks of working memory information to form understanding, knowledge and routine ideas.

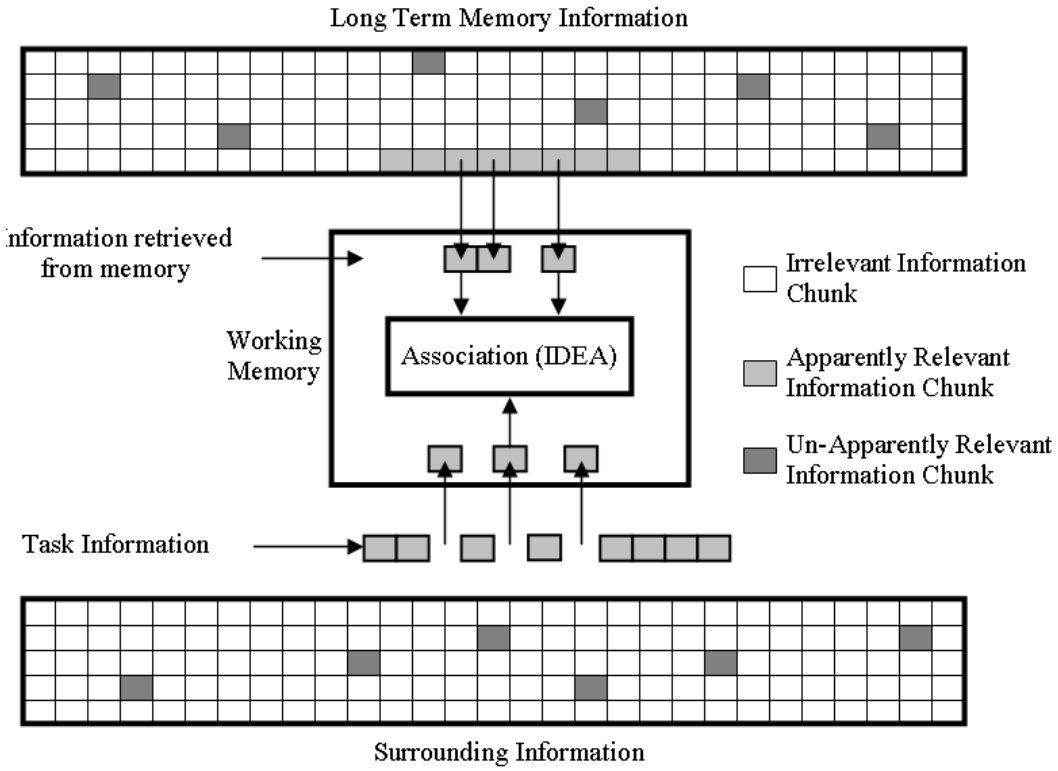


Figure 3-3 – Cognitive model for *routine* idea generation

3.3.2 Creative idea generation

Creative idea generation relies partly upon luck and the ability to associate distinctly different chunks of information. – "*Much of the difficulty in everyday problems may hinge on finding the relevant information in memory or the environment required to solve the problem*" (Eysenck and Keane 2000, p.408).

Figure 3-4 is a development of the approach, it shows how after the incubation phase, Un-Apparently Relevant information may arise from either Inner Locations (I) from the long term memory or Outer Locations (O) from surrounding information and is used to form new associations and therefore more likely to result in creative ideas.

Type 'I' creative idea generation: In this instance, the suppression or block may be lifted during the incubation phase enabling this new chunk of information to form an association. Alternatively, whilst pondering or searching through mental archives, a new Un-Apparently Relevant chunk of information may be found and associated.

Type 'O' creative idea generation: During the incubation the designer may come across a surprise result, an interruption or another form of stimulating information to inspire a creative association. This information may have been situated within sensory distance of designer but was not previously considered Relevant or accessed whilst other Relevant information was within the working memory.

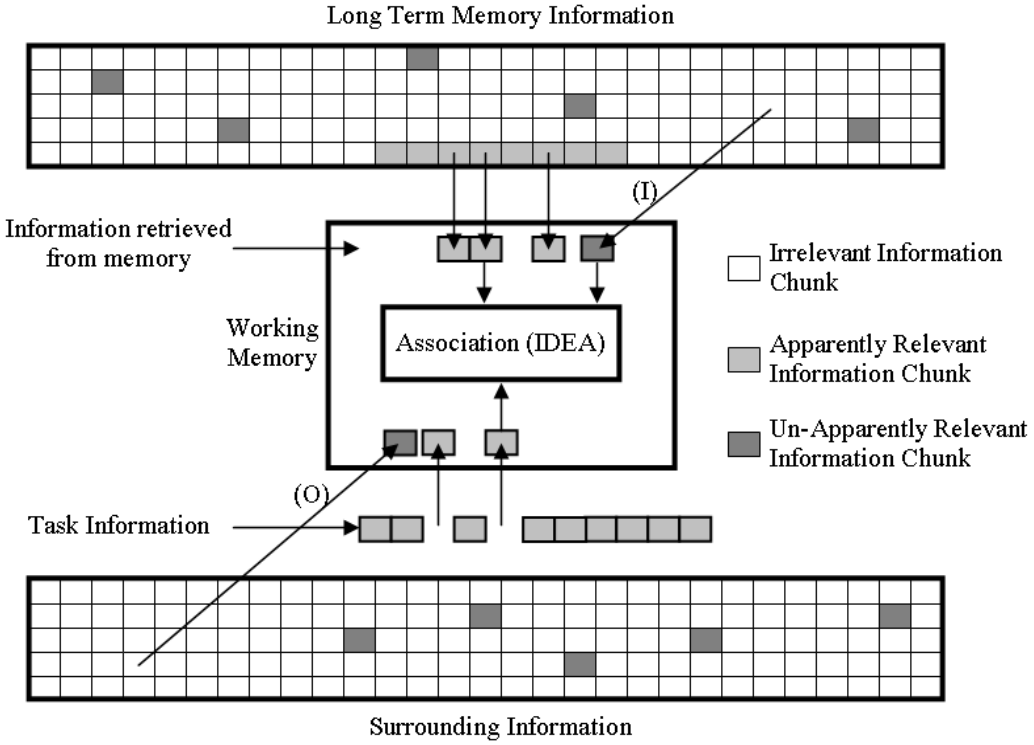


Figure 3-4 – Cognitive model for *creative* idea generation

"*The current favoured account seems to be that any new information introduced into a problem or met in the environment may activate related concepts in memory and result in sudden emergence of solution*" (Eysenck and Keane 2000).

In light of the theory described so far in this chapter, the literature review now extends to more relevant papers dealing with idea generation and creative stimulation. Research into creative Stimuli will aim to aid type 'O' creative idea generation by prompting Un-Apparently Relevant Outer information.

3.4 Creative stimulation

In this section the relatively small amount of literature regarding creative stimulation is reviewed. This literature predominantly comes from the fields of cognitive, experimental and social psychology. It was observed that several of the papers regarding social creativity became relevant, especially through the analysing of the effects of idea exposure which can also be deemed as a form a Stimuli. To support this it has been stated (Hinsz 1999; Perttula and Sipila 2007) that the input from other group members may both stimulate and interfere with the mental processes of group members.

3.4.1 Dependant variables

The creative performance of a group is often measured using two dependant variables of; number of ideas (Nijstad *et al.* 2002; Perttula and Sipila 2007), and, idea quality (Wierenga 1998). In creativity research, 'number of ideas' was said to be the most common measurement of the creative output (MacCrimmon and Wagner 1994), however, depending on the nature of the research, 'quality of ideas' is of varied importance, ranking higher when Originality is at preference over speed of idea production.

From the vast quantities of literature reviewed, it would appear that creative quality of an idea is generally defined by the propositions of 'novelty' and 'appropriateness' to a task (Massetti 1996). In earlier research (see section 2.3.2) the author(s) proposed the addition of a third criterion: Un-Obviousness to a task (Howard *et al.* 2006). These dependant variables of idea frequency and idea quality characterise the types of research which will directly influence the research in this thesis. All papers and research reviewed within this section will concern at least one of these variables.

3.4.2 Idea exposure

The affects of idea exposure on idea generation has gained much research interest over recent years. This interest is predominantly due to the dominance of the technique of brainstorming within industry despite the growing body of results stating that nominal groups (individuals working alone) outperform interactive groups (individual working together) (Dugosh *et al.* 2000; Paulus and Yang 2000). Conversely, there are as many accounts showing that interactive groups can outperform nominal groups (Perttula and Sipila 2007). Despite the disagreement over that actual performance of groups against individual, the theoretical benefit of idea sharing has been adequately proven (Dugosh *et al.* 2000; Dugosh and Paulus 2005; Warr 2007) putting poor actual group performance down to other factors such as free riding an production blocking.

In a particularly well conducted study (Nijstad *et al.* 2002), the idea of group stimulation and interference was tested in terms of the information being conveyed by the group members. The theory of idea generation behind this work known as SIAM (Search for Ideas in the Associative Memory) is complementary to the authors view developed earlier this chapter, on idea generation. SIAM proposes that idea generation is split into two stages; first the knowledge activation stage where a search cue is placed in the short term memory to retrieve Relevant knowledge from the long term memory; second the idea production phase where the information is associated to form ideas and concepts.

It is thought by Nijstad (2002), like several others, that the long term memory is structured into localised sets of strongly interconnected and semantically related features. In the previous section it was suggested that these semantically related features are based on design entities of function, behaviour and structure (section 3.5). The research looked at the effects of Stimuli in terms of two different categories. Firstly, the semantic category which the Stimuli came from; either, the same semantic group (homogeneous Stimuli), or, one of the other 34 different semantic categories (diverse Stimuli). Secondly, the sequence of exposure, where the

Stimuli were either experienced; five ideas at a time form the same semantic category (clustered sequence) or; in a random, un-clustered order (random sequence).

The results showed that both semantic categories in either sequence are beneficial to productivity, producing greater numbers of ideas to the control group (no Stimuli). It was also shown that clustering had no effect over random sequence on productivity. As expected, more diverse ideas were produced as a result of the diverse Stimuli as apposed to the homogeneous Stimuli and the control condition. This is supported by findings by Liikkanen and Perttula (2006), showing that there are a notably greater number of ideas generated in a particular category depending on the particular stimulus experienced, and Satzinger (1999) finding ideas produced tend to by related to the paradigm of the stimulus experienced.

Within-category fluency is the total number of non-redundant (un-replicated and useful) ideas produced over the number of semantic categories (diversity) they are spread. Unsurprisingly, higher levels of within-category fluency came from those stimulated by homogeneous Stimuli rather than the diverse Stimuli or control group. These results are supported by Warr (2006) where it was shown groups refine ideas (homogeneously) and develop linearly better than individuals.

The sequence by which the Stimuli were revealed to the subjects did have an effect on the train of thought of the designer. As hypothesised, the Stimuli exposed in a random sequence lead to slight cognitive interference, resulting in ideas switching between categories, thus reducing the clustering which can efficiently populate semantically similar groups of ideas. However, the sequence of exposure had no affects on fluency. An interesting finding from the results of the control group showed that it took approximately 40% more time to produce an idea from a different semantic group, than from a semantically similar group.

In a more recent, but related experiment (Kim *et al.* 2005), it was shown that minor changes to the task assignment can lead to vastly different ideas being generated. In

the experiment the designers were given a design task, one with contextual cue[1] A, one with contextual cue B and a control group without C. The ideas generated by A, B and C fell into quite different solution categories. The affect of key word Stimuli, was also tested with similar results.

3.5 Creative stimulation using design entities

The previous sections state the Locations where information can be drawn from, and relate the Apparent-Relevance of the information to the Un-Obviousness of the ideas generated. The cognitive mechanism shows that these chunks of information combine by association within the working memory. This section will provide insight into the types of entities within the information chunks that are associated during idea generation. This work comes full circle from earlier theory in chapter 2, where different design types are categorised by the position of the creative output in terms of function behaviour and structure. In this section it is proposed from related literature, that ideas are also produced by associating entities of function, behaviour and structure and thus each of these entities can be used as Stimuli in raw form.

3.5.1 Stimuli from design entities

The theoretical grounding of the three design entities (Gero 1990) was not produced for the purpose of creative Stimuli. The theory places behaviour as the central entity and thus by definition a structure cannot infer a function and vice-versa without inferring a behaviour first. For the purposes of explaining creative Stimuli, information may stimulate an idea if one of the information's entities can be likened to one of the problems entities and so another entity can be transferred. As an example, if the stimulus (information chunk) exhibits a function the same as that required by the design task, the behaviour of the stimulus' function could be used as part of the solution.

[1] Contextual Cue – A piece of information hinting at a particular context. Example: design footwear to run around on a football field. Here the work football would be a contextual cue.

It is on this basis of identifying functions that many entity based creativity tools have been developed. Animal Crackers (Grossman and Lloyd 2006) is another entity-based creativity support system. Here an attempt is made to solve the problem by relating the desired behaviour of the solution to behavioural entities of animals. This principle has now been extended to biomimetic use within the TRIZ contradiction matrix (Vincent and Mann 2002; Vincent *et al.* 2005; Vincent *et al.* 2006).

The TRIZ (Altshuller 1999) contradiction matrix is a typical example of a creativity support system pushing information related by design entities. Here the problem is phrased into the contradiction it solves, such as reduce 'weight of stationary object' but retain 'strength'. By consulting the contradiction matrix solution principles or Stimuli are prompted such as 'mechanics substitution', 'taking out', 'preliminary action' and 'cheap short-living objects'. These principles have previously solved problems of a similar nature. This is a particularly advanced tool as it returns solutions as entities of Functions, Behaviours and Structures within the principles.

Benami's (2002) paper is the most thorough of the literature researched regarding design entities. The paper concerns creative stimulation through a cognitive mechanism, processing the three design entities. Within this seminal paper a cognitive model is proposed describing the sequence by which the 'pre-inventive' design entities lead to the expression of an idea. One of the cognitive processes of particular interest is the Transformation process. This refers to the manipulation of entities after association has been made.

During Benami's (2002) study, designers were given a design problem and were grouped into four groups each given one information entity as stimulation. In addition to the three regular entities a knowledge entity is also included comprising of a complete concept, in this case a bicycle (see Table 3-2). Each group was given the following design problem: *To develop alternative boat designs that are also human powered.*

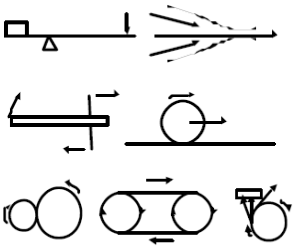
Function	Form	Behaviour	Knowledge
A fish swims under water A duck paddles on the water An otter dives under water An elephant blows out of trunk A bird flaps its wings A monkey swings on branches An owl hunts at night			

Table 3-2 – Information Entities for Idea Stimulation (Benami and Jin 2002)

As part of the protocol analysis (think aloud method), Benami fully transcribed design sessions into separate creative design episodes (groups of statements leading to new idea(s)). Once this has been done researchers independently encoded the creative design episodes into four segments: 1. The creative property with the stimulating entity, 2. The cognitive process, 3. The internal operation, 4. The external operation. The results suggest that if a knowledge entity is broken down into its subsequent function, form and behaviour entities it will stimulate more ideas from a designer (See Figure 3-5).

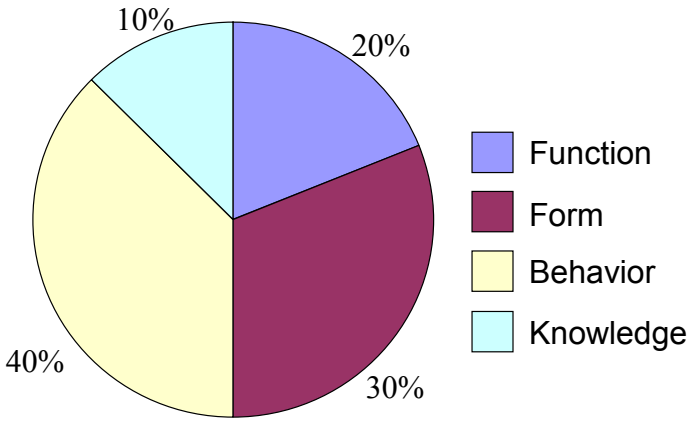


Figure 3-5 – Ideas Stimulated per Entity (Benami and Jin 2002)

The results are in keeping with what would be expected, considering behaviour is the central entity of the three. One other possible explanation given for the results in Figure 3-5 is that the knowledge entities and functional entities were fixating towards

one solution therefore suppressing the number of ideas and the novelty of the ideas. The more ambiguous relationships of the form and behaviour entities lead to greater numbers of and more novel ideas. However, the author believes that there is another reason, related to the experimental problem. Since this problem is formed to achieve a function, proposing other functions alone should theoretically not aid the designer as only new behaviours and structures can achieve the desired function.

It was also stated that the creative properties of meaningfulness and relevance were essential to idea generation. If information has no meaning to the designer or relevance to the problem then it has no use. This is supporting of the theoretical work described earlier in this chapter

Though this is regarded an excellent study into this very complex area, there were several shortcomings of the methodology used. Firstly, the format in which these entities were represented. It can be seen from Table 3-2 that the function entity Stimuli were represent in textual form; the knowledge entity Stimuli in pictorial form and; the form and behaviour entity Stimuli in abstract diagram form. This must be taken into account as it has been empirically proven that 'graphical' representations outperform 'textual' representation in terms of idea stimulation (McKoy *et al.* 2001).

Secondly, neither the creation of the design problems nor the evaluation of design solutions were preformed under realistic or industrially-based conditions. The third issue is in the use of students as apposed to professional engineering designers. These pitfalls were taken into account when constructing the research methodology in section 1.4.

3.5.2 Ideas from design entities

At simple and constrained levels function, behaviour and structure entities can be used not only to prompt ideas in the form of creative Stimuli, but can generate ideas and solutions. Giampa (2004) developed a CACD (computer aided conceptual design) tool based on the 'functional aspects' implicit to the product requirements set in the clarification of task phase. Here function is split into two categories (Deng 2003):

Purpose Function: The designers purpose or intention of a design (what it's for).
Action Function: How the designer wishes the product to function or work (what its does).

This is similar to Chakrabarti's (1998) two part definition stating the higher levels abstraction related to the purpose function and lower levels of abstraction relating to the action function. The conceptual design activity sees the designer gradually transform purpose functions into action functions in an often unconscious way (Giampà *et al.* 2004). Suh (1990) takes this one step closer to embodiment in axiomatic design where the Functional Requirements (Action Functions) are related to Design Parameters in the physical space.

The CACD tool proposed provides an excellent way to attribute these Action functions to the specific components (design parameters) involved. Through a knowledge base the functions of each component or series of components are recorded and can be replaced with others exhibiting the same overall function. This is association at a low level of abstraction as these are just mechanical components which fit in a schematic layout as apposed to high level solution analogies. In this instance the association is, made and implemented by the tool.

3.6 Discussion and conclusions

During this chapter on idea generation and Stimuli, a theoretical mechanism has been described showing how Outer (to the human body) information can be used to stimulate both routine and creative ideas (section 3.3). This research will now move on to focus on the how variations in this Outer information, termed creative Stimuli, will affect creative idea generation.

From both the theory and the review of related studies the following conclusions have been drawn:

- Location and Apparent-Relevance are identified as key categories when considering the potential of chunks of information as creative Stimuli.

- It is identified that time is required in order to produce Un-Obvious and thus creative ideas, supporting the need for an incubation phase.
- Association is detailed as the mechanism by which chunks of information are used to form an idea.
- Creative idea generation is distinguished for routine idea generation by the Un-Apparently Relevant chunks of information used during association, satisfying Objective C.
- Dependant variables of idea frequency and idea quality have been identified.
- There are varying accounts for the performance of groups against individuals for idea generation. However, stimulus in the form of idea exposure (in controlled conditions) has proven to have positive affect.
- Homogeneous Stimuli can help to linearly develop ideas or produce closely related ideas, whereas diverse Stimuli help to provide novelty of ideas.
- In controlled but contrived conditions behaviour entities stimulate idea generation better than functional, structural and knowledge entities.
- For constrained problems, association by design entities can be used by tools to prompt Stimuli as well as complete solutions.

It was observed during the literature review that few studies observed professional engineers (Benami and Jin 2002; Kim *et al.* 2005), the rest of the studies used students. It was also observed that sample sizes were relative small in terms of experimental research, using roughly 60 students on average. To further emphasise this lack of research and thus the general lack of understanding regarding creative Stimuli, only 1 study used more than one design problem and no studies have as yet use real industrial design tasks. For many studies this meant artificially contrived evaluations of the ideas produced by participants.

Although these studies have developed the understanding of the field significantly, they have yet to provide results proven in professional practice. These observations were very influential when constructing the research methodology (section 1.4).

During this chapter a theoretical model of creative idea generation is proposed showing how Outer information can be use to stimulate creative ideas. The question to now be addressed is what are the criteria that influence the performance of information for the use of creative Stimuli? And, what are the criteria by which to measure the performance? These questions will be dealt with in the next chapter.

4 Establishing the research criteria and framework

This chapter details the first stage (the criteria stage) of the Blessing's research methodology (Blessing and Chakrabarti 1999) for the particular task at hand. The purpose of this stage is to identify the influential criteria in terms of the variables involved in the research. Section 4.2 will give an overview of the Major Areas regarding stimulating information (Figure 4-8). The chapter will then progress describing the variables associated with the characteristics formed by the three major overlapping Major Areas and success criteria, thus satisfying Objective D.

4.1 Introduction to information

Information management is the key research theme of the Design Information and Knowledge (DIaK) group within the Innovative *design* and Manufacture Centre (I*d*MRC) providing the funding for this research. In this section the term information is reviewed from its various viewpoints from within information management literature. This short review of related literature states how information is defined (section 4.1.1) and how it may be affected by accessibility (section 4.1.2), formality (section 4.1.3), activity (section 4.1.4), and source (section 4.1.5).

4.1.1 Data, Information, Knowledge

The definition for Information is robust throughout the literature. According to the dictionary definition of information (Collins 2006):

information:

1. *knowledge* acquired in any manner; facts
2. the meaning given to *data* by the way it is interpreted.

This fits closely with common definitions from within the domain choosing to reference related terms such as data and knowledge. Information, knowledge and data are often used interchangeably with little understanding of the differences between each term, much the same as creative, innovative and inventive. A general distinction between these terms is in the perception to each individual in terms of the

level of understanding or as a state of mind (Alavi 2001), as described in systems operator shown in Figure 1-1. Whilst Tuomi (1999) states that knowledge must exist before information can be formulated and before data can be measured to form information, most definitions work the opposite way defining from data to knowledge. Court (1995) proposed the following definitions:

Data: defined as known facts or specific details held within the global form of this information.
Information: defined as something that is told, knowledge, items of knowledge and news, containing an amount of data (both useful and not)
Knowledge: defined as the ability of the individual to understand information and the manner with which to handle, apply and use it in a given situation. This is built upon the individuals' experience, gained by establishing the relationships between different items of information and data.

This fits closely with the definitions currently being used under the Design Information and Knowledge (DIAK) theme at the University of Bath, Innovative *design* and Manufacturing Research Centre (I*d*MRC) proposed by Hicks et al. (2002).

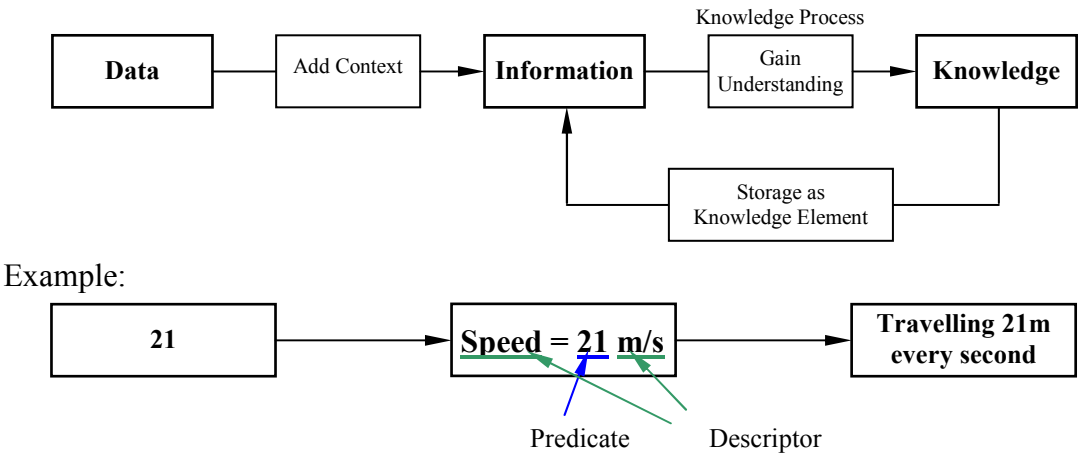


Figure 4-1 – Definition of Data, Information and Knowledge.

Figure 4-1 shows how data is viewed simply a magnitude with no meaning only relative to other data. When context is added to this data it then becomes information with a predicate (the data element) and a descriptor (the context) and can be applied to situations and worked with. The minimum amount of data or bits of information that can be transferred as information is defined by the Shannon entropy (Shannon and Weaver 1949). It is in the understanding of information by a knowledge process that forms knowledge in the form of a knowledge element.

The key point to be taken from these definitions is that knowledge is always stored either as a knowledge element (Hicks *et al.* 2002) or as information once it is articulated and presented in the form of text, graphics, words, or other symbolic forms (Alavi 2001). This can be re-accessed where it may be reinterpreted depending on the situation to reform knowledge. This fits closely to the cognitive model of idea generation proposed in section 3.3 where the Inner information is stored as a knowledge element in the long term memory. Bringing information into the working memory requires a knowledge process.

4.1.2 Accessibility based

Numerous studies of engineers have found that accessibility was the factor that most influenced their selection of source (Fidel and Green 2004). However, the concept of accessibility is ambiguous, meaning different things to different designers and researchers. This subsection will describe a small selection of these facets.

McMahon et al. (2004) offers this classification schema of knowledge in terms of whom and to how many it is accessible and how it is viewed:

Commodity: Knowledge as artefact, handled in discrete units.
Community: Knowledge is not defined universally, but as defined in practice.
Tacit: Personal Knowledge
Explicit: Codified as company information resource (Nonaka 1996)

Of this, the commodity view is the most accepted and useful. It is the explicit knowledge that is particularly valuable for this research as the Stimuli generated Internally to the domain is based on explicit knowledge. The use of tacit knowledge as Stimuli may be a potential future study, though it has been said to be "inherently difficult, even impossible to reveal, organise and codify" (Darlington 2002) making it difficult to guide to effective Stimuli.

Tacit and Implicit forms of knowledge are often wrongly confused. This is most probably due to the fact that they are both "on the same side of the iceberg" (Huet 2004) of the Iceberg Model (Quintus 2000) identifies visible and hidden knowledge (see Figure 4-2). However, where tacit knowledge is useless to the wider organisation beyond the creator, implicit knowledge is defined to account for tacit knowledge that on introspection can be made useful to the organisation.

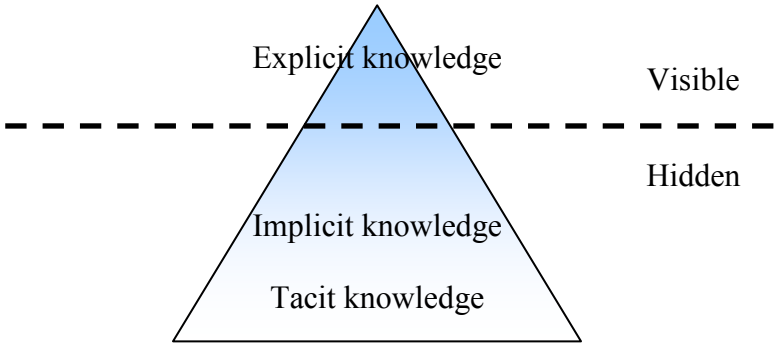


Figure 4-2 – Iceberg model of visible and hidden knowledge (Quintus 2000)

Explicit knowledge: Knowledge that is readily accessible and amenable to precise and clear expression. This knowledge may already be codified or is codified in principle.

Implicit knowledge: Knowledge that is currently not easily revealed and organised but is in principle available to introspection and by careful inquiry may be made explicit and thus 'raised above the surface'.

Tacit knowledge: Inherently difficult, even impossible to reveal, organise and codify. This type of knowledge includes 'know how' which is gained by experiential learning – and it cannot be communicated by others and is not susceptible to being 'raised above the surface' by introspection.

4.1.3 Formality based

Formal information is a type of information that provides a specific context and measure (Hicks *et al.* 2002). It provides a structure or a focus so that individuals exposed to it may infer the same knowledge from it, such as formal education, where the content and order is prescribed. To achieve this, formal education is structured and sufficiently decomposed to describe all the necessary information, which includes facts upon which the inferred knowledge is based.

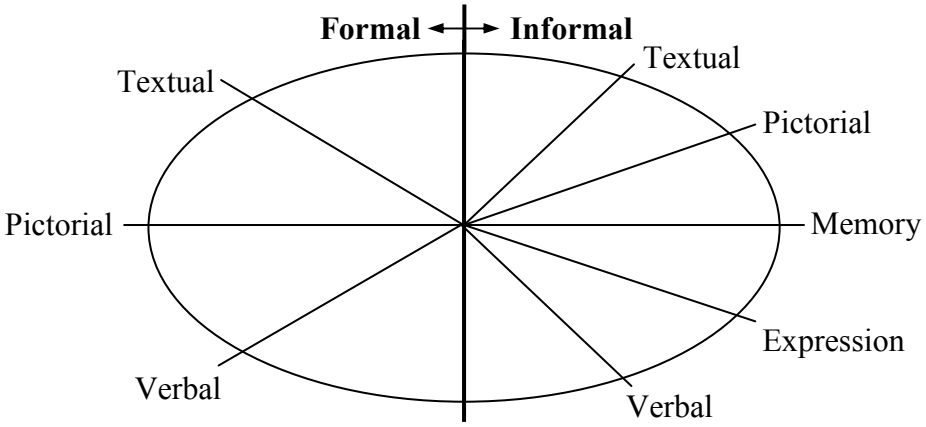


Figure 4-3 – Formal / Informal Information (Hicks *et al.* 2002)

For the purposes of communication, formal information can be sub-classified into three categories that relate to the representation or conveyance of the information.

Allen (2003) continued investigations in this area. One notable outcome of the work was the distinction and description of formal and informal classes of information used for the selection of standard components. The research presents the categorisation of 3 types of formal information:

Primary Information: The direct workings of a component.
Secondary Information: Consequential component characteristics (e.g. dimensions of the component).
Tertiary Information: Information relating to the operation, installation or service of a component.

Informal information is considered by the authors to encompass unstructured information (Hicks *et al.* 2002). The majority of which is either personal information or information that is developed through interaction between two or more individuals. Here the subjects and predicates may not be clearly defined; the information may change dynamically as content is altered or added. Indeed this varied and dynamic information set provides the generation of various knowledge perspectives for the individuals taking part, and it is this variation that both stimulates and develops the creative and decision-making processes.

Allen (2003) categorises this type of information under the following four headings:

Memory: Information acquired though personal experience in design
Verbal: Information conveyed between colleagues
Written (Unstructured): Information in note format typically in log books
Written (Structured): Information that can be found in a catalogue environment but can be loosely defined as informal i.e. structured notes

The worth of this informal information has been realised with studies initiated in order to help capture store and disseminate this information. Huet et al. (2007) are currently investigating methods for the capture of informal design transactions in meetings, one major observation being that engineers are untrained in taking minutes, leave much information unrecorded. McAlpine (2006; 2006) is currently undertaking a study regarding informal information stored in logbooks. It was estimated the roughly 65% of engineering logbooks were accessed daily for important tasks such as ‘answering colleagues questions’ and ‘verifying work’.

Closely related to accessibility, the formality of information is an important characteristic when investigating the irretrievability for purposes of creative stimulation. Formal documents are characterised by explicit knowledge representation, whereas informal characterised by tacit and implicit representation. The issues of codification for effective retrieval are the same.

4.1.4 Activity based

In a study by Collet (2004) working with engineering design departments, it was observed that designers spend roughly 2/5th's of their time modifying information with 15% of time spent retrieving the information. In a previous studies by Boston the figure for information searching was estimated at 25 % and Lowe's (2002) survey of information usage in the aerospace industry stated that on average 20% of designers' time is spent searching for and absorbing information.

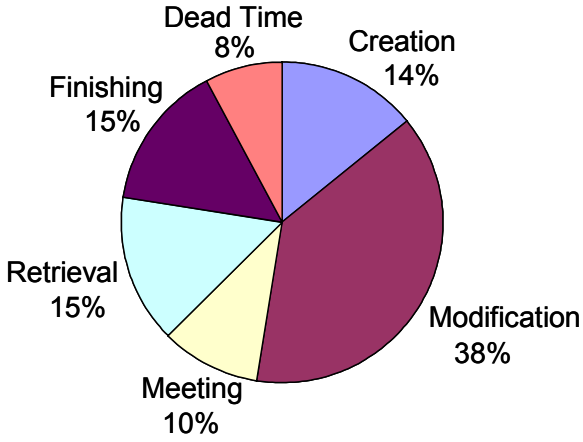


Figure 4-4 – Engineering Designer Activity Profile (Collet 2004)

Hales (1986) carried out a study in an engineering firm designed to improve understanding of the nature of design in an industrial context. The study included extensive observations of designers' activities over the duration of a large engineering project.

One objective of the research was to determine the focus of effort over the duration of each design phase. This work identified and recorded time spent on core design activities and on additional supporting activities. Information retrieval is one of the six identified supporting activities identified by Hales (1986), and makes up a significant proportion of effort towards the end of the design project. This is illustrated in Figure 4-5, where different aspects of project effort (measured in hours) are shown for each phase of the project (Campbell 2004).

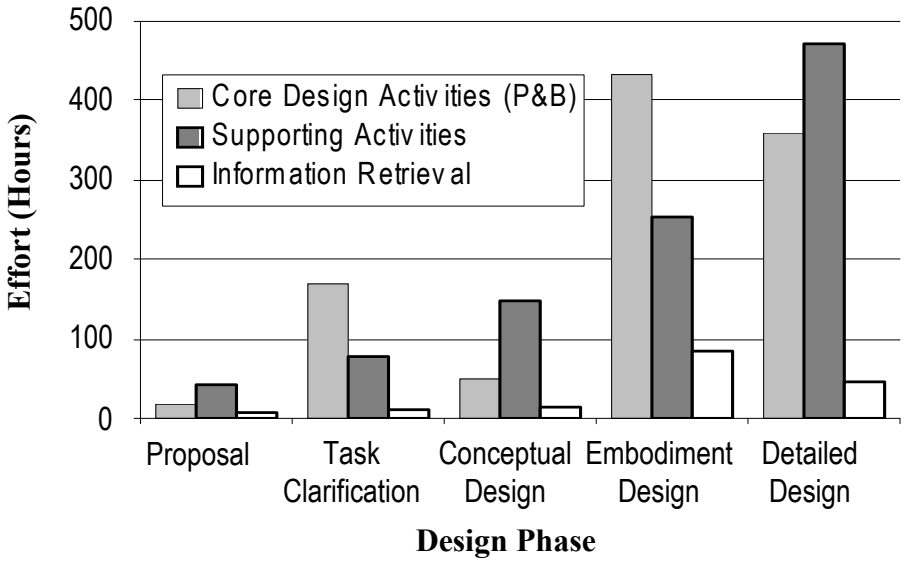


Figure 4-5 – Effort spent on information retrieval in design projects (Hales 1986)

When considering the provision of information support for designers a low-level, detailed typology of design information may be helpful. Court (1995) presents the following ***types*** of information, which are considered in the sense of ***what*** information is required to undertake a particular task.

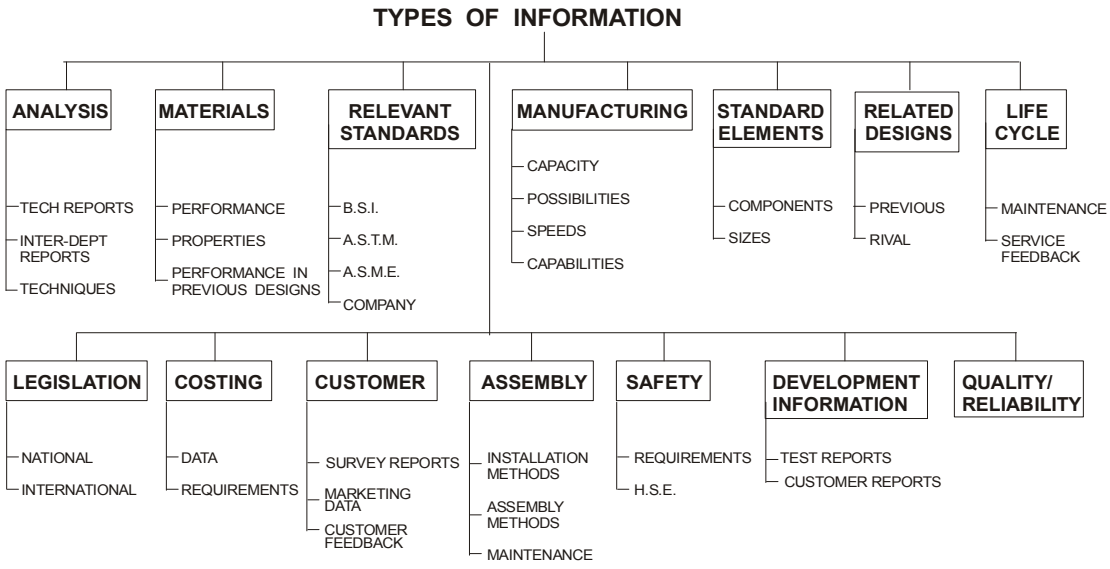


Figure 4-6 – Information is required to undertake a particular task (Court 1995)

Notice that there is no explicitly labelled information type for creation or innovation, strange since it is such an important and large aspect of design. What does a designer use for Stimuli?

4.1.5 Source based

Court (1995) also investigates a related question regarding the ***sources*** of information or, ***where*** these types of information reside. Figure 4-7 shows the sources of information defined as where such information can be obtained.

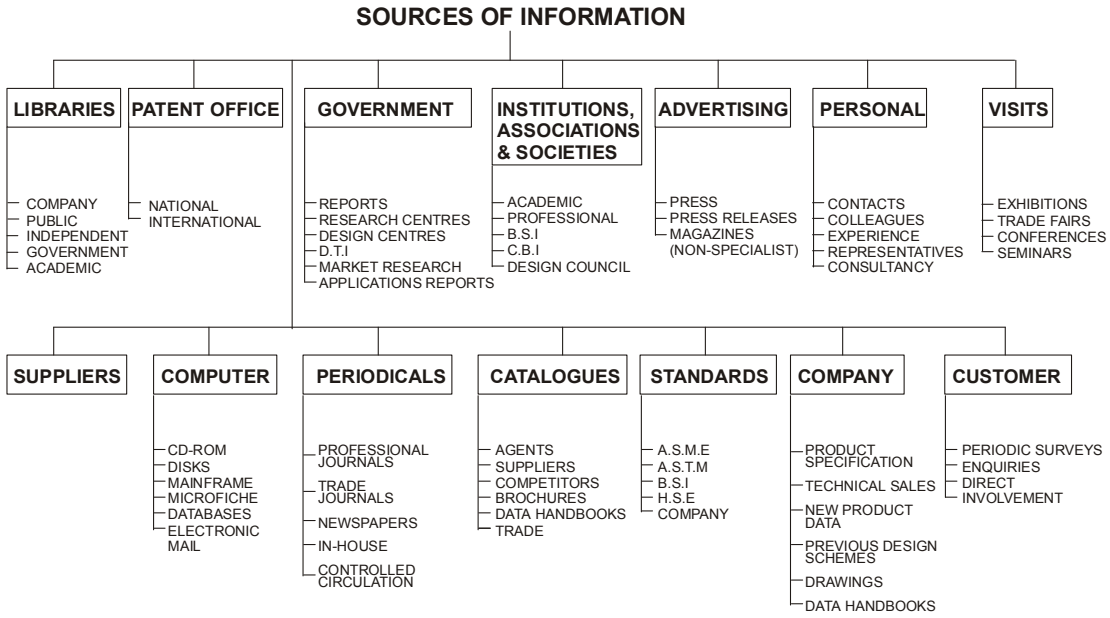


Figure 4-7 – Sources of information (Court 1995)

It is important to note that this review was published 1995, before widespread use of the Internet for information provision, so these sources generally refer to the physical location of information (Campbell 2004).

It is important to note that information is not always requested and therefore taken from its source. Boston (1999) offers 3 categories by which information can enter the design process; randomly (serendipitous), through request (pulled) and through logic (deduction).

There are various sources from the above that could potentially be stimulating to creativity. Future studies could be conducted to compare the information from each of these Outer Locations. These could be extremely useful to designers if a method can be constructed to push relevant information from such sources during creative design activities.

4.2 Major Areas influencing creative stimulation

From the literature reviewed in chapters 2 and 3, section 4.1 and the participation action research in the following chapter, it became apparent that the task, the designer performing the task and the information itself are the Major Areas affecting the performance of creative Stimuli. Figure 4-8 shows these three Major Areas, of which a framework for influential criteria is developed around. The diagram represents the different characteristics[1] (Table 4-1) in terms of the seven different combinations of the information, task and designer. In addition, each of the characteristics is represented by a number of variables[2].

The variables associated to the characteristics in position (1) (Table 4-1), central to Figure 4-8, are thought to be of the most influential to creative idea stimulation and will be used to differentiate between Stimuli generated Internally and Externally to the industrial domain (see section 6.4). It was also thought of paramount importance to establish the large number of potentially influencing variables associated with the various characteristics in Figure 4-8. This serves to highlight the limitations of the research and illuminate the potential areas for future studies to focus. It will also focus the areas to observe in study 2, the information audit (see chapter 5) providing a dependable context in which to frame the results and conclusions from the prescriptive study, study 3 – Stimuli testing.

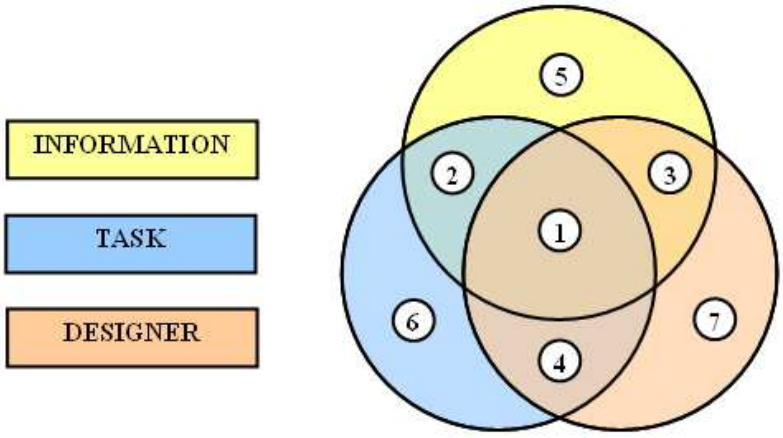


Figure 4-8 – Stimuli characteristics and the 3 Major Areas

[1] **Characteristic** – A category of the dimension under study.

[2] **Variable** – Refers to the characteristics influence on the stimulation of idea generation.

Table 4-1 gives a description of the various characteristics positioned in Figure 4-8.

Characteristic	Description
(1)	Subjective, task dependent information characteristic.
(2)	Context dependent information characteristic.
(3)	Subjective information characteristic.
(4)	Subjective context characteristic.
(5)	Context independent information characteristic.
(6)	Task characteristic.
(7)	Designer characteristic.

Table 4-1 – Characteristics effecting the creative stimulation

The above characteristics are derived from the interactions between the three Major Areas will now be discussed more thoroughly. In sections 4.3 the independent variables associated with characteristic (1) (Table 4-1) are discussed in more detail. These variables are at the focus of this research.

Section 4.4 details the other variables that may affect creative stimulation and are associated with characteristics (2)-(7) in Table 4-1. Though several of these variables are controlled, several are uncontrolled due to the industrial setting of the study and many are both, reasonably uncontrollable and immeasurable, even under 'experimental conditions' given today's techniques and technology (example, a designers mood).

In section 4.5 the dependant variables are detailed. These are constructed both from the theoretical work of section 2.3.2 and the literature reviewed on dependent variables in section 3.4.1. These variables will be used as a measure to test the effectiveness of the Stimuli.

4.3 Independent variables

The independent variables for this research have a **task and designer dependent information characteristic (1)** (Table 4-1). This means that each of the associated variables is affected by changes to; the information being used, the task it is being applied to, and the designer accessing it. The two variables associated this characteristic are described in Table 4-2. As an example, consider the first of the two variables, 'Relevance'. The Relevance of information is hypothesised (section 6.4) to have an effect on how stimulating it is to creative idea generation. As Relevance is a variable attributed to characteristic (1) it is dependent on:

- **The information**: If the information is changed it may become more or less relevant to the designer and task, thus becoming more or less stimulating to creative idea generation.
- **The task**: If the task is changed the information may become more or less relevant to the new task, thus becoming more or less stimulating to creative idea generation.
- **The designer**: If the designer is changed the information may be more or less relevant to the new designer, thus becoming more or less stimulating to creative idea generation.

The second variable of Un-Apparentness is conceptually more difficult to understand. It refers to how Apparently the information is related to the problem and thus solution. This variable also has characteristic (1) and is affected by the information, the task and the designer.

Variable	Definition
Relevance	How relevant the designer deems the information to the task.
Un-Apparentness	How Un-Apparently the information is related to the task in the subjective view of the designer.

Table 4-2 – Subjective, context dependent information variables

These variables along with those detailed in section 4.4, satisfy Objective D by identifying the influential criteria.

4.4 Other variables

The following variables are to be described along with the characteristic with which they are associated to (Figure 4-8). Though these variables are not all controlled, study 2 will provide exemplar profiles of information uses within Crown Packaging, allowing the reader to form a context in which the conclusions are drawn regarding both the independent and dependant variables.

4.4.1 Task dependent information variables

Variables associated with the **Task dependent information characteristic (2)** (Table 4-1) are theoretical, referring to the how the information is related to the task without subjective judgement from the designer. The variables associated to this characteristic are described as design entities detailed in section 3.5. These variables have been studied in previous research (Benami and Jin 2002; Kim *et al.* 2005; Perttula and Sipila 2007) and are believed by the author to be the fundamental link between the stimulus, the task and the solution. However, once the designer attempts to make the connection between the stimulus and the task, variables associated to characteristic (1) become dominant.

Variable	Definition
Function	Describes the teleology of the object (what it is for).
Behaviour	Describes the attributes derived from the structure (what it does).
Structure	Describes the components of the object and their relationships (what it is).

Table 4-3 – Task dependent information variables

	Function	Behaviour	Structure
A	Heating water	Conduction	Pan and Flame
B	Cutting paper	Sheering	Scissors

Table 4-4 – Examples of design entities

For certain tasks the entities in example A (Table 4-4) will be more stimulating than the entities in example B, perhaps closely linked to Relevance.

4.4.2 Subjective information variables

The **subjective information characteristic (3)** refers to how each designer relates to the information. Therefore, if either the information or the designer is changed/altered the associated variables (Table 4-5) will be affected. As an example consider the variable of 'meaningfulness'. If the information is changed, it may have a different intrinsic meaning to the designer. Also, several designers may find different meaning from the same information depending on their background.

The variables associated with this characteristic are extremely difficult to control. The effects of these variables may be lessened by the use of formal information, making the information less ambiguous and more objective.

Table 4-5 was partially populated by creative properties termed from previous literature (Benami and Jin 2002). The other variables were intuitively generated. This is again not a definitive list, it serves as exemplify the main variables of the characteristic.

Variable	Definition
Meaningfulness	What a particular piece of information means to a designer. Certain chunks of information may have more or different meaning to one designer than it does to another.
Reliability/trust	The designer perceived reliability of information. Perhaps increased if the information is taken from a reputable journal.
Newness	How new that particular piece of information is to a designer, perhaps a new fact, constraint or functional requirement.
Flexibility	How many different contexts the designer deems the information viably usable.
Loudness	How grabbing the information is (i.e. loud colours, volume etc.)
Clarity	How clear the information is to designer relative to other information.
Divergence	The capacity for multiple uses for the information.
Incongruity	Conflict or contrast between elements in analogy.
Emergence	Degree to which information inspires designer.

Table 4-5 – Subjective, task independent information variables

4.4.3 Subjective context variables

The **subjective context characteristic (4)** addresses the relationship between the designer and the task. The variables associated with this characteristic (Table 4-6) will be altered if either the task or the designer is changed. As these variables are not related to the Major Area of information and thus creative Stimuli they are beyond the scope of this study. However, this is a very important characteristic containing extremely influential variables such as motivation, interest and authority.

In order to reduce the influence of these variables, descriptive study 2 should select designers consistently depending on the task being worked on. This will be lessened by having similar mixes of authority amongst the designers in standard innovation projects with studying only the case company's employees so they have a similar goal.

The initial variables in Table 4-6 were derived from discussion with the case company and the related literature. Again, this is not a definitive list and can be added to by the various studies from social and cognitive psychology.

Variable	Definition
Motivation	Describes the motivation of the designer to progress the task.
Authority	Describes the authority of the designer on the task at hand.
Interest	Describes the designer's goal for the particular task.

Table 4-6 – Subjective context variables

4.4.4 Context independent information variables

The **context independent information characteristic (5)** is associated with information variables (Table 4-7) that are independent on either the task or the designer. As an example consider the variable 'medium' from Table 4-7. The medium of information, whether it be video, textual, graphical etc. will always be the same, unaffected by the task or the designer.

At an earlier stage of this research these context independent variable were to be the independent variables in an experiment with engineering students using large sample sizes, though were deemed less important. All of these variables will be fixed throughout study 3, with the exception of the 'Source' variable which is closely related to both the Relevance and Apparentness (see section 6.4).

Variable	Definition
Reusable	If stored and re-accessible of reduced to memory storage.
Movable	Whether movable form its location.
Medium	Whether video, audio, text, smell, diagram etc.
Carrier	How it is accessed, through which packages etc.
Formality	How formal information is in comparison to other information.
Complexity	How complex the information is – time taken to absorb.
Quantity	Amount of information given.
Mechanism	How the information is obtained (Push/Pull)
Source	Where the information may come from.
Anchoring	Whether the information cannot be removed from its surroundings or context, such as a 'No Entry' sign.
Tone	Visual defences in colour or variation in audio tone.

Table 4-7 – Information Variables

4.4.5 Task dependent variables

The variables associated with the **task dependant characteristic (6)** (Table 4-8) describe how the differences in the design task may affect idea stimulation and will affect the output independent of either the information or the designer. As an example, the stage of the Design Process in which the ideas are being generated may have large impact on the dependent variables. During the construction of study 3 it was possible to control these variables with an exception of the driver.

Variable	Definition
Output	Whether a product of process is produced.
Risk	The varying levels of impact of the product.
Driver	Whether the task is technology or market driven
Detail	The level of detail in the design task.
Constraint	Extent of constraints within the design task.
Team Size	Whether a group or individual project
Domain	Which industry and department the project is in
DP Stage	Stage of the design process.

Table 4-8 – Problem Variables

4.4.6 Designer dependent variables

The variables associated with the **designer dependent characteristic (7)** are affected by changes in the designer generating the ideas. This is as always the most difficult characteristic to deal with and is almost impossible to do in an industrial setting. In order to lessen the effects, particular case examples were selected for study 3 containing similar designers with the same brainstorm facilitators.

Typically captured variables are related to the designer's personal details. However, perhaps more influential variables would be gained from KAI scores, preferential learning types and Belbin team roles (Kirton 1977; Barron and Harrington 1981; Belbin 1981). Some background research was conducted in study 2 detailing information profiles of the designers under study (see section 5.6).

4.5 Success criteria (dependent variables)

The creative performance of a group is often measured using two dependant variables of; number of ideas (Nijstad *et al.* 2002; Perttula and Sipila 2007), and, idea quality (Wierenga 1998) From the vast quantities of literature reviewed, it would appear that creative quality of an idea is generally defined by a propositions 'novelty' 'appropriateness' to a task (Massetti 1996). In earlier research the author(s) proposed the addition of a third criterion: Un-Obviousness to a task (Howard *et al.* 2006). To

make idea generation activities most efficient for engineering design processes, creative design ideas need to be defined as a Original, Appropriate and Un-Obvious and relate to either the 'function', 'behaviour' or 'structure' of a design solution.

The dependent variables or success criteria will enable descriptive study 2 (chapter 7) to determine how stimulating the information types are towards creative idea generation. From the literature review on dependent variables (section 3.4.1), it was realised that the majority of credible studies within the area use two variables, frequency (or fluency) of idea generation, and quality of idea generation. From the robust theory presented in section 2.3.2 regarding the creative output, the quality of a creative idea can be defined by its Originality, Appropriateness and Un-Obviousness.

Variable	Definition
Frequency	How quickly ideas are being produced, or how may ideas are produced in a given time period (section 3.4.1)
Originality	Whether the idea is related to a completely new concept (Original) or not (routine), see the creative output, section 2.3.2
Appropriateness	Whether the idea is disregarded (inAppropriate) or is selected for further exploration, see the creative output, section 2.3.2
Un-Obviousness	Whether the idea was generated quickly (Obvious) or after a longer period (Un-Obvious), see the creative output, section 2.3.2

Table 4-9 – Dependant Variables (Success Criteria)

These theoretically supported success criteria, described in Table 4-9, satisfy Objective D and the means for idea evaluation.

The criteria described throughout this chapter must now be understood in an observable industrial context. The following descriptive study will attempt to do so. Through means of action research and an empirical observational study, a case can be built for a creative support incorporating the above mentioned criteria.

5 Descriptive Study 1 – Information use audit

Engineering design is now commonly considered an information driven activity (Campbell 2007), from defining the task, to communicating the final design. From the theoretical work proposed in chapters 2 & 3 it is shown how the information accessed and thus information management, has a direct influence on ideas produced and the eventual design types created. This is supported by other researchers in the field of engineering information management who also show that the design process is essentially an information processing activity (Hales 1986; Poelman 2005) or an information transformation process (Hubka *et al.* 1988; Ognjanovic 1998; Lowe *et al.* 2004).

Furthermore, in a variety of studies (Court *et al.* 1998; Boston 1999; Lowe 2002; Collet 2004) have concluded that design engineers spent 15-30 percent of their time in acquiring, using and communicating information. Engineering like other disciplines therefore not only relies heavily on information but spends large quantities of time and resources to manage it. It is thus not unreasonable to assume that within this information rich environment there is great potential to source and make available, information in the form of creative Stimuli.

The following chapter describes an observational information audit carried out at Crown Packaging, representing descriptive study 1 of the overall methodology (section 1.4). This chapter progresses by first describing the case company (section 5.1) and the participatory action research performed within its innovation department (section 5.2). The following section then describes the empirical, observational methods by which data was captured during the information audit (section 5.3). The following subsections then describe the results of the information audit in terms of the three Major Areas (see section 4.2), the information Major Area (section 5.4), the task Major Area (section 5.5) and the designer Major Area (section 5.6). Finally, the chapter is summarised and discussed (section 5.7) fully addressing Objective F.

5.1 Opportunity with Crown Packaging

The company associated with the research is Crown Packaging. Crown is a specialist packaging manufacturing company working mainly with metal packaging. In order to maintain competitive advantage over the plastics packaging industry they have to rely on innovation for new and more efficient products and have set up a specific in-house innovation department to do just that.

This provided a good source of expertise, information from a typically hard engineering industry. In return for this information, Crown hoped to gain some insight into how their department could become more creative or enhance the use of creative resources.

This section will introduce the reader to the research project collaborator. After describing the relationship and research opportunity with Crown Packaging the research methodology chosen (section 1.4) will be easier to understand in context. The following information was selectively compiled from the Crown Packaging corporate website (Crown Packaging 2008) and attempts to provide an insight into the credibility of the industrial collaborator.

5.1.1 History

1892 – A new industry is created. Foreman and inventor William Painter patents the 'crown cork' and soon thereafter starts the Crown Cork & Seal Company of Baltimore.

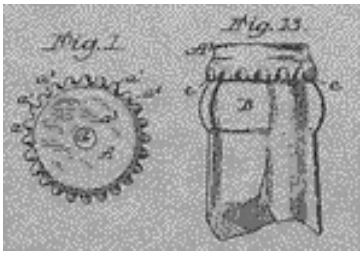


Figure 5-1 – Figures from the patent of the crown cork (www.crowncork.com)

1996 – Crown Cork & Seal acquires CarnaudMetalbox, Europe's leading manufacturer of metal and plastic packaging, and becomes the world's packaging leader.

Figure 5-2 – CarnaudMetalbox, a crown company (www.crowncork.com)

Crown has since sold their plastics and. In a recent study (O'Hare *et al.* 2008) benchmarking innovation hubs of large multinational companies, Crown Packaging was given as a successful example due to its organic growth.

5.1.2 Global location

American Division	European Division	Asia-Pacific Division
Corporate and division headquarters in Philadelphia, PA	Division headquarters in Paris, France	Division headquarters in Singapore
59 plants spanning Canada to Brazil	82 plants in Europe, Middle East and Africa	13 plants covering China and Asia
7,500 employees	14,000 employees	1,900 employees
US $2.7 billion net sales in 2006	US$3.8 billion net sales in 2006	US $482 million net sales in 2006

Figure 5-3 – Crown's geographical statistics (www.crowncork.com)

The plant in which the majority of research is conducted is a research and development plant based in Wantage, UK. This plant contains an *innovation hub* consisting of 6 engineering/industrial designers, attached to other research based departments such as engineering, marketing, intellectual property, etc. This includes on-sight manufacture and assembly testing facilities for new products in development.

5.1.3 The Crown philosophy

The company puts its world-class performance down to their attention paid to the following seven key dimensions Figure 5-4. Of particular interest is the managing innovation dimension where it is stated that individual contribution to product, process and systems innovation is encouraged and rewarded. Crown's drive for research, development and innovation made them extremely perceptive collaborators for this research.

Figure 5-4 – Seven key dimensions to world class performance

(www.crowncork.com)

5.1.4 Segmentation: Markets, businesses, project types

The following information categorises Crown projects from three different perspectives of market, business division and customer involvement.

Market

Drinks	Food	Health & Beauty	Household & Industrial
			

Table 5-1 – Crown's divisions of products and services (www.crowncork.com)

Businesses

Aerosol	Beverage	Food	Metal Closures	Speciality Packaging
				

Table 5-2 – Crown's product business divisions (www.crowncork.com)

During this study the researcher experienced live projects from all business divisions. During the action research phase of the research methodology the researcher acted as project manager for a real metal closures project.

Project types

Crown innovation projects are also classified by the relationship with the customer. The first of these categories is the *customer* project in which a customer approaches crown with a need or a brief. The customer is the usually involved throughout the innovation process. The second category is the *carrot* project which is where a project is started with a customer in mind to entice at a later more realisable stage. *Generic* projects are the third type, comprising of projects to both broaden corporate knowledge being beneficial to a multitude of customers.

5.1.5 The innovation process

Figure 5-5 shows Crown's innovation process. This process is also positioned within the framework of generic design processes (Table 2-1). This shows that the process fits the general framework of standard design processes and thus can be comparable

and accepted as a fair representation of engineering design when studied. One notable difference is in the use of synonymous terms to name their phases, the 'conceptual' design phase has become the 'ideas' phase, the 'embodiment' phase becomes the 'concept' phase and the 'detailed' design phase becomes the 'feasibility' phase. At the end of each phase is a stage gate requiring specific deliverables and an evaluation and selection process. This research lies predominantly within the Ideas phase concentrating on the group brainstorm.

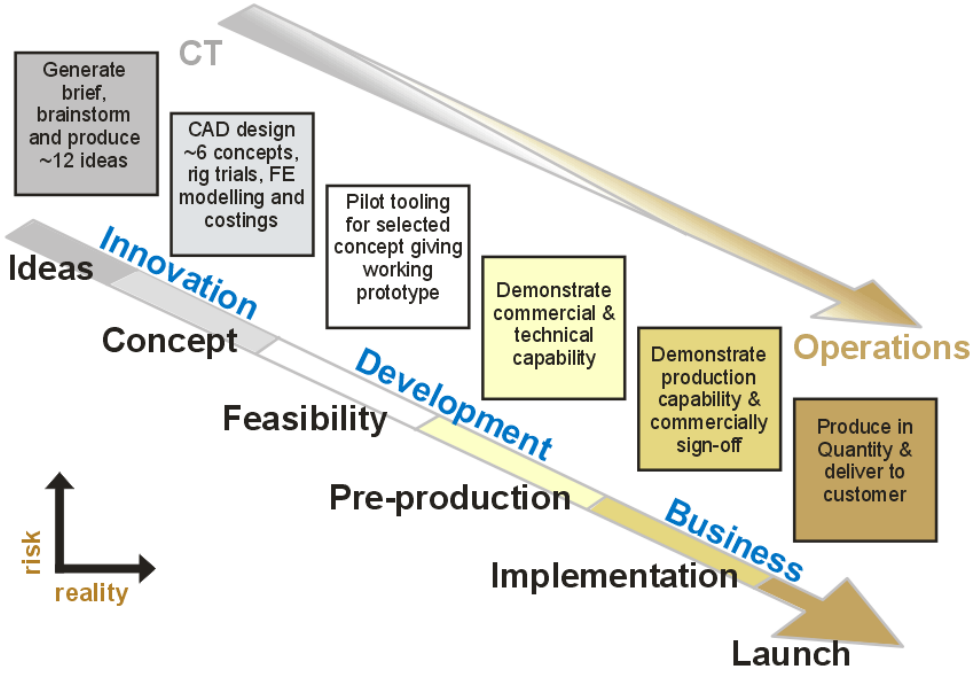


Figure 5-5 – Crown Innovation Process (www.crowncork.com)

5.2 Participation action research – Project Drizzle

The following section details the participation (Ottosson 2003), participatory (Greenwood *et al.* 1993) or insider action research (Ottosson and Björk 2004; Bjork and Ottosson 2007) conducted during descriptive study 1, in order to help satisfy Objective D. This section will describe the purpose of this action research study (section 5.2.1) before detailing the important aspects of project Drizzle (section 5.2.2) with regards to Descriptive study 1 (chapter 5), the prescriptive study (chapter 6) and descriptive study 2 (chapter 7).

5.2.1 Purpose of the study

This study was designed to establish the background for the key research studies in chapters 6 and 7. This will also provide the author with a greater understanding of the domain, process and general day to day workings within Crown Packaging. The study was undertaken early on in the research. In the order of actual occurrence, the theoretical work and the identification of a knowledge gap was incomplete before undertaking this study. It therefore served the purpose of refining the theory and criteria to suit further study at Crown Packaging, in order to provide findings of practical and industrial benefit as well as academic gain.

As well as being useful for defining the criteria (chapter 4), this study also played a vital role in descriptive study 1 of Blessing's methodology (Blessing and Chakrabarti 1999). The knowledge gained would provide far greater insight and understanding when capturing and reflecting upon the observations being made of other designer's behaviour. This was of great importance to second part of descriptive study 1 (section 5.4) and descriptive study 2 (chapter 7), where this 'insider' (Bjork and Ottosson 2007) knowledge was of significant benefit.

5.2.2 About project Drizzle

The following project is still under development at Crown and its details must be to a large extent omitted due to the confidentiality agreement. The project originated from the metal closures division as a Carrot project to entice a particular customer (see section 5.1). In comparison to the average project it was dimensionally and functionally constrained. This made the project technically challenging as it proved difficult to propose behaviours that could both be embodied within the constraints, whilst providing the desired functions.

The project contained all the necessary phases and documentation; enabling a far greater understanding of both the information being used and accessed than the information seen in the audit and the projects being undertaken in descriptive study 2 (chapter 7). Example pages of the documents/files are shown in Figure 5-6 to Figure 5-9. The creation and use of these files were of direct relevance to the prescriptive

study (chapter 6). The brief documents contain the musts and desirables vital to the search dimension of the Information Management Creative Stimuli (IMCS) tool proposed in section 6.3, to identify relevant projects. The brainstorm, in which all the group design ideas are produced and captured within the brainstorm document, became the central activity to descriptive study 2. It is these design ideas that will be assessed to test the performance of each stimulus.

Figure 5-6 – Brief document

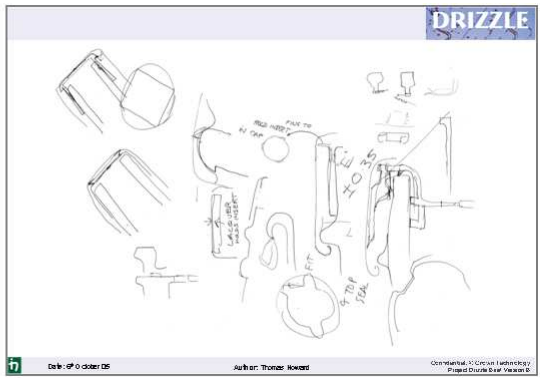


Figure 5-7 – Brainstorm/ideas document

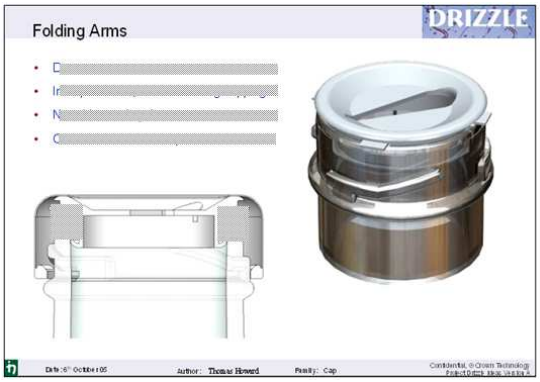


Figure 5-8 – Concepts document

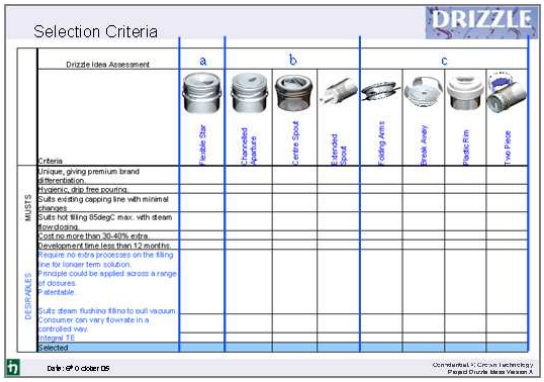


Figure 5-9 – QFD document

The Concepts document contains concepts formed from previous design ideas in the process. It is these concepts that are to be retrieved and used as Stimuli by the IMCS tool (section 6.3). The QFD file provides a mechanism by which to select the most appropriate concepts from within a project.

The project was taken to the second stage gate at the end of the concept stage (and the innovation phase) of the Crown innovation process (Figure 5-5). The project is currently still live and in development. A patent application has been filed for the selected concept. Without this valuable first hand experience of the design process at Crown the author would have been unable to see the potential of Internally generated Stimuli or its industrial application.

5.3 Data capture method

From this point onward, this chapter will describe the second part of the descriptive study, regarding the observational information audit. The following section details the method that was used to capture data during the observational study. This begins with the capture procedure (section 5.3.1) describing the techniques used, including the construction of the recording chart and the various categories under which the information types were recorded. In section 5.3.2, the supporting or contextual information being recorded is described, before the describing the other categories with quantities in sections 5.4, 5.5 & 5.6.

5.3.1 Capture procedure

An empirical, observational research method was used to record the information uses by the designers. This was done by taking momentary snapshots of the designer's activities at around intervals of 5-10mins. To record the data, the author was positioned central to the six designers so each could be observed in turn, the time and date being noted at the beginning of each snapshot with time after to analyse the categories the information fits into.

A pilot trial was first undertaken for content analysis, using approximate categories to analyse the sorts of information use that were being observed. It became evident that the category scheme was not complementary. The main problem appeared to be that, by observation, information uses were often too complex to narrow down to single distinct categories. The use of electronic data capture software was trialled on two workstation computers, however the results were unrealistic as they provided little reflection of intention and did not encompass non-electronic forms of information.

Eventually a recording scheme was proposed, tested and selected. Though this required interpretation from the author, it was often obvious what information was being used at a given moment, any unobvious information uses were clarified on the authors request to the designer. The scheme recorded data covering the 3 Major Areas, covering the designer, the task/project, the information and some contextual information. A recording chart was established to aid the simple and consistent capture of the data. An example page of this recording chart for a single designer is shown in Figure 5-10.

													Source						Carrier										Medium						
Date	Time	Project	Stage	Type	Business	Location	Relevant	Pushed	Pulled	Input	Output	Internet	Intranet	Public File store	Local File store	Surrounding	Person	Email	CAD	Imaging	WP Software	Paper	Photo	Phone	Material	F2F Dialogue	Verbal	Textual	Diagrammatic	Physical	Multiple	Administration	Activity			
14/11/2005	14:56	S6	2	G	BC	Ad	1	1	1	1	1					1			1						1					1	1		Using CAD for close up detail and proto for real			
14/11/2005	15:10	S6	2	G	BC	Ad	1		1		1			1					1														Looking at dimensions and prep for print			
14/11/2005	15:45	S6	2	G	BC	Ad			1	1							V	1									1						Replying to email			
14/11/2005	16:06	S6	2	G	BC	Ad	1		1	1				1					1										1				Adjustingpofile dimensions of seal and sketchin			
14/11/2005	16:06	S6	2	G	BC	Ad	1		1	1						1						1							1		1		Adjustingpofile dimensions of seal and sketchin			
14/11/2005	16:23	S6	2	G	BC	Ad	1	1		1						1						1							1				Chris giving old zipit folder			
14/11/2005	16:32	S6	2	G	BC	Ad,D			1	1	1					1									1					1			Looking for the laptop			
18/11/2005	09:36	S6	2	G	BC	Ad	1		1	1				1					1										1				Working on profile of the clicker an inset and se			
18/11/2005	09:47	S6	2	G	BC	Ad	1		1	1				1					1										1				Woking on lever section of clicker			
18/11/2005	10:03	S6	2	G	BC	Ad	1		1	1				1					1										1				Observing motion of clicker lever arm			
18/11/2005	10:13	S6	2	G	BC	Ad	1	1			1						b								1	1	1						Discussing motion of clicker lever arm			
18/11/2005	10:13	S6	2	G	BC	Ad	1	1			1			1					1										1		1		Discussing motion of clicker lever arm			
18/11/2005	10:22	S6	2	G	BC	Ad	1	1	1	1	1						b								1	1							Discussing tolerance with reference to enginee			
18/11/2005	10:22	S6	2	G	BC	Ad	1	1	1	1	1					1						1							1		1		Discussing tolerance with reference to enginee			
18/11/2005	10:33	S6	2	G	BC	Ad	1		1	1				1					1										1				Woking on lever section of clicker			
18/11/2005	10:40	S6	2	G	BC	Ad	1		1	1				1					1										1				Looking at seal on can dmnsions and thinking			
18/11/2005	11:03	S6	2	G	BC	Ad	1		1	1				1					1										1				Observing motion of clicker lever arm			
18/11/2005	11:17	S6	2	G	BC	Ad	1	1			1				1							1							1				Looking at eng drawing of clicker			
18/11/2005	11:29	S6	2	G	BC	Ad	1		1	1				1					1										1				Working in X-Section of clicker			
18/11/2005	14:47	S6	2	G	BC	B	1	1	1	1	1						b,6x								1	1							Meeting on clicker			
18/11/2005	14:47	S6	2	G	BC	B	1	1	1	1	1			1					1										1		1		Meeting on clicker			
18/11/2005	14:47	S6	2	G	BC	B	1	1	1	1	1					1									1					1	1		Meeting on clicker			
18/11/2005	14:55	S6	2	G	BC	B	1	1	1	1	1						b,6x								1	1							Meeting on clicker			
18/11/2005	14:55	S6	2	G	BC	B	1	1	1	1	1			1					1										1		1		Meeting on clicker			

Figure 5-10 – Recording chart for information audit

Approximately 1000 snapshots were taken in total over a 40 hour period. These were then organised and represented in graphical format in sections 5.4, 5.5 & 5.6. The full set of raw unsorted data can be seen in Appendix A.

Data gathered regarding the information profiles of the designers (section 5.6) was gathered by 15 minute structured interviews. During these interviews a recording chart was filled out by both the interviewee and interviewer, regarding personal details of the designers, their career history and personal sources of information they use.

5.3.2 Contextual information

The supporting or contextual information captured for each snapshot was essentially for administration purposes. These included the date, time, location and project code. Also recorded was whether the information use was deemed as an engineering design task or an administrative task. Whether the information use was 'related' to the project the designer was currently working on was also captured.

A brief description of the activity was also recorded for the purposes of re-evaluation if needed. As the information uses were not always simple enough to fall into one single category, it was also recorded whether the information use was over 'multiple' categories.

5.4 Information profile

The information use audit is the focal section of the descriptive study addressing Objective F. Its purpose is to categorise and record the information accessed and used by Crown Technologies Innovation department. Though there has been no direct link made between the information inputs recorded and inspiration towards a creative output, it gives an insight into the types and quantities of the information used by creative individuals. This can be then used as a comparison with other such departments or individuals in future studies. The data collected and the results displayed during this section relates to the Information Major Area (Figure 5-11).

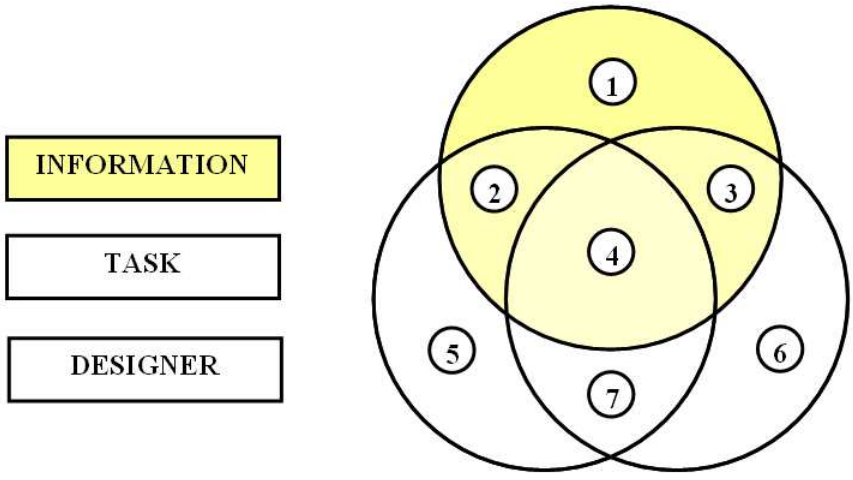


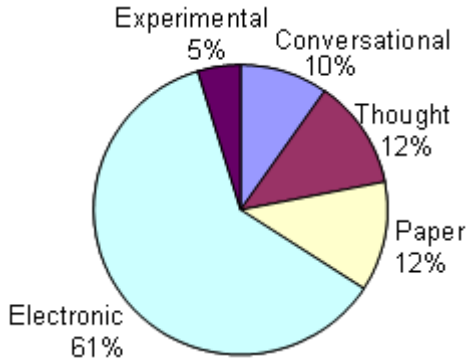
Figure 5-11 – Information Major Area (see chapter 4)

In previous research (Collet 2004), an interesting categorisation of communication based information was devised, where the information is categorised in terms of the format (see Figure 5-12).

Conversational	Mental	Paper	Electronic	Experimental
Face-to-face Internal Phone Calls External Phone Calls	Thought (Input only) Memory (Output only)	Formal Paper Informal Paper Paper Diagrammatic	Web Electronic-Textual Electronic-Tabulation Electronic-Diagrammatic	Part Inspection (Input only)

Figure 5-12 – Communication categories (Collet 2004)

Figure 5-13 and Figure 5-14 from Collets (2004) study show the information accesses and outputs for design engineers. It is interesting to note that 61% of the information inputs come in electronic form. In order to complete a significant study on creativity with regards to information inputs, experimental work can be done electronically and integrated work systems to take advantage of this.



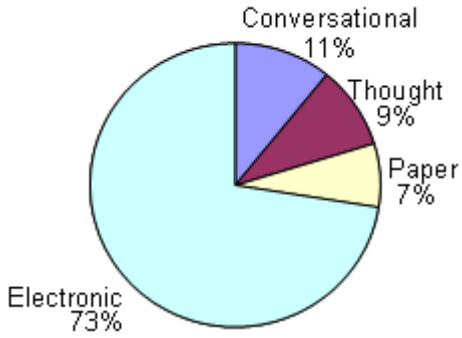


Figure 5-13 – Information access mode groups **Figure 5-14 – Output transfer method groups**

The findings from Collet's (2004) study are very useful. They highlight the overwhelming dominance of electronic information use within engineering departments. In this information audit these categories will be further broken down to identify opportunities.

The types of information uses captured by the recording charts were separated into three categories: the source of information (section 5.4.1), the carrier of information (section 5.4.2) and the medium of information (section 5.4.3). Also analysed are the various streams of information use (section 5.4.4) which correspond to the retrieval mechanism described in Figure 5-15, linking the source, carrier and medium.

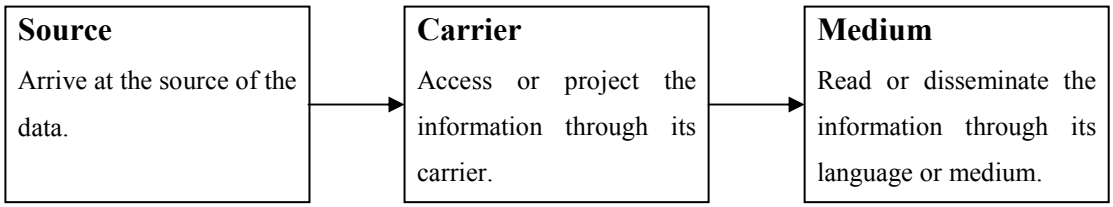


Figure 5-15 – Information use process in terms of source, carrier and medium.

5.4.1 Information sources

Definition: Information source refers to the location that the information is accessed relative to the single designer being observed in the snapshot.

The different information sources recorded during the information use audit are:
Internet: Information stored on the internet.
Intranet: Information stored on the intranet.
Public File Store: Information from 'public' or shared file store (e.g. achieves etc.).
Local File Store: Information from 'local' file store (e.g. hard drive, desk draw etc.).
Surrounding: Information from surrounding workspace and environment.
Person: Information stored within person.

The data captured from observing the information used by all 6 designers was compiled in order to produce Figure 5-16. The relative quantities of the different sources of information used are conveyed (in **bold**) including the range between designers for each source. The hatched area in Figure 5-16 represents the snapshots that contained multiple sources. Within this hatched region are the relative proportions of the information sources.

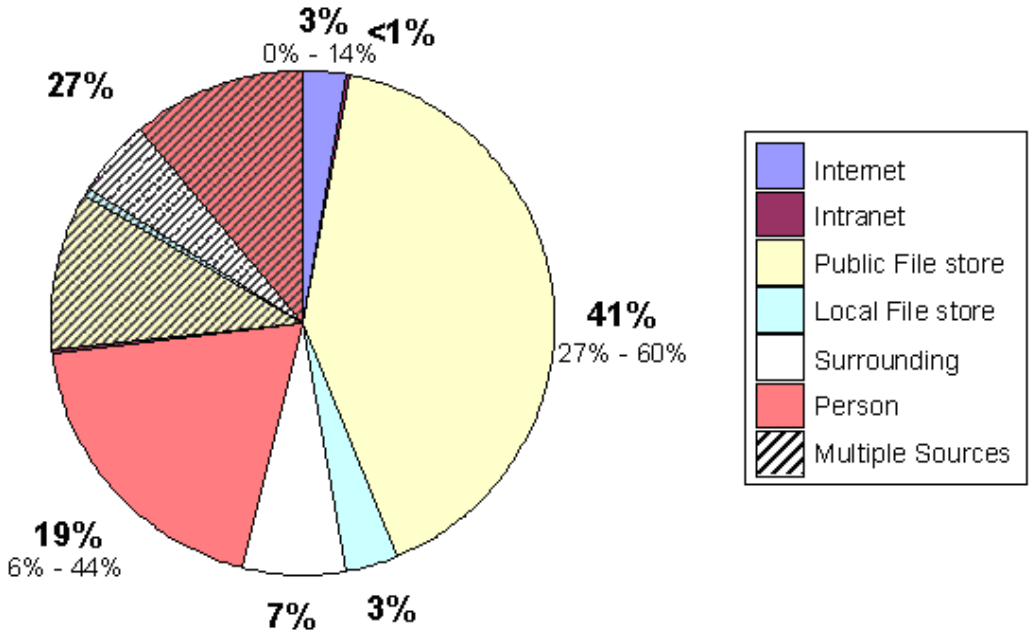


Figure 5-16 – Sources of Information accessed by the innovation department

From the data it can be seen that roughly half the information used is sourced on the public file store. This is encouraging as the search and retrieve strategies can occur at this single source rather than several private sources. Although these files can be freely accessed by other members of the company it is unlikely to happen without the creators presence and consultation, as most of the information uses are contained within the project files. These files are naturally more formal than other sources making them easier to search and retrieve.

It came as a surprise how little the company intranet was used (<1%). This is full of extremely detailed and specific information useful to the designers. It was observed through the audit and backed up by the action research that this information space was used predominantly for retrieval or very specific quantitative information, such as sizes, tolerances, production speed etc. Also of surprise was how relatively little the Internet was used. Due to the sheer amount of information available, a future study should be conducted to retrieve Un-Apparently Relevant information as Stimuli. Also used to a small degree were local or private file stores. This gives an indication as to the move towards the recording and formalising working documents, rather than creating personal mock-ups.

5.4.2 Information carriers

Definition: Information Carrier refers to the way in which the information is accessed by the designer. There are many possible carriers, of which some are linked very closely to the types of the information they carry.

The different information carriers recorded during the information use audit are:
Email: Information transferred via email.
CAD: Information carried using computer aided design software.
Imaging Software: Information carried using pictorial bitmap/vector editing software.
Word Processing Software: Includes spreadsheets, databases, Internet browsers.
Paper: Information carried on paper (hard copies).
Photo: Information carried via photography.
Phone: Information Carried via the phone (specific to verbal).
Material: Physical Information by manufactured and natural material.
Face to Face Dialogue: Conversation.

The data captured from observing the information uses by all 6 designers was compiled in order to produce Figure 5-17. The relative quantities of the different carriers of information uses are conveyed (in **bold**) including the range between designers for each source. The hatched area in Figure 5-17 represents the snapshots that contained multiple carriers (27%). Within this hatched region are the relative proportions of the information sources.

Despite dealing with the ideas and concept phase at the front end of the design process the majority of information uses by the innovation department are carried using CAD packages previously related to the later stages of embodiment and detailed design. Working with these packages along with imaging software early on in the design process is in many senses constraining to creativity. However, the detailing and three dimensional viewing tools with transformations such as rotate, zoom, cross-section and render support the designers working memory making them very useful for structural aspects of creativity.

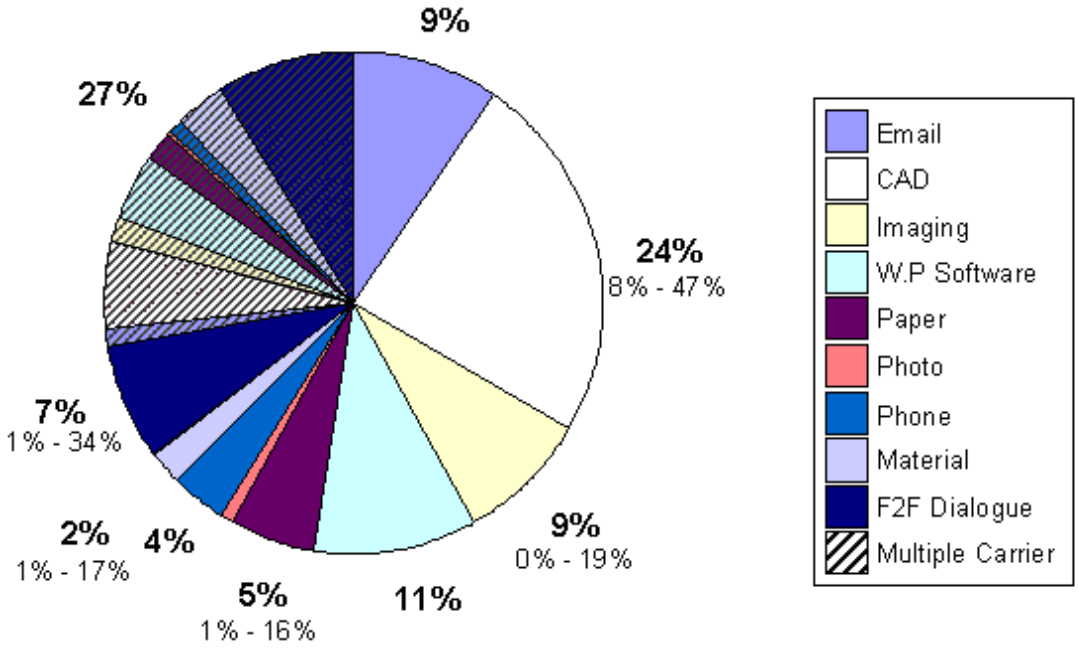


Figure 5-17 – Carriers of Information accessed by the innovation department

Despite being an innovation department, the majority of information uses were electronically carried. Only 14% of the information uses were using paper and material information carrier. However, they comprised a large percentage of the multiple use information carriers, suggesting that they are useful communication tools for supporting face to face dialogue.

5.4.3 Information medium

Definition: Information Medium refers to the visual representation of the information. It effectively refers to the language that the data in communicated. It became apparent that there were only four distinct mediums of information being analysed during this study.

The different information mediums recorded during the information use audit are:
Verbal: Information represented verbally as speech (also includes sound).
Textual: Information in the form of text.
Diagrammatic: Abstract representation of information e.g. graph, sketch, simulation.
Physical: A three dimensional physical object e.g. prototype, model, coffee mug.

The data captured from observing the information uses by all 6 designers was compiled in order to produce Figure 5-18. The relative quantities of the different carriers of information uses are conveyed (in **bold**) including the range between designers for each source. The hatched area in Figure 5-18 represents the snapshots that contained multiple carriers. Within this hatched region are the relative proportions of the information sources.

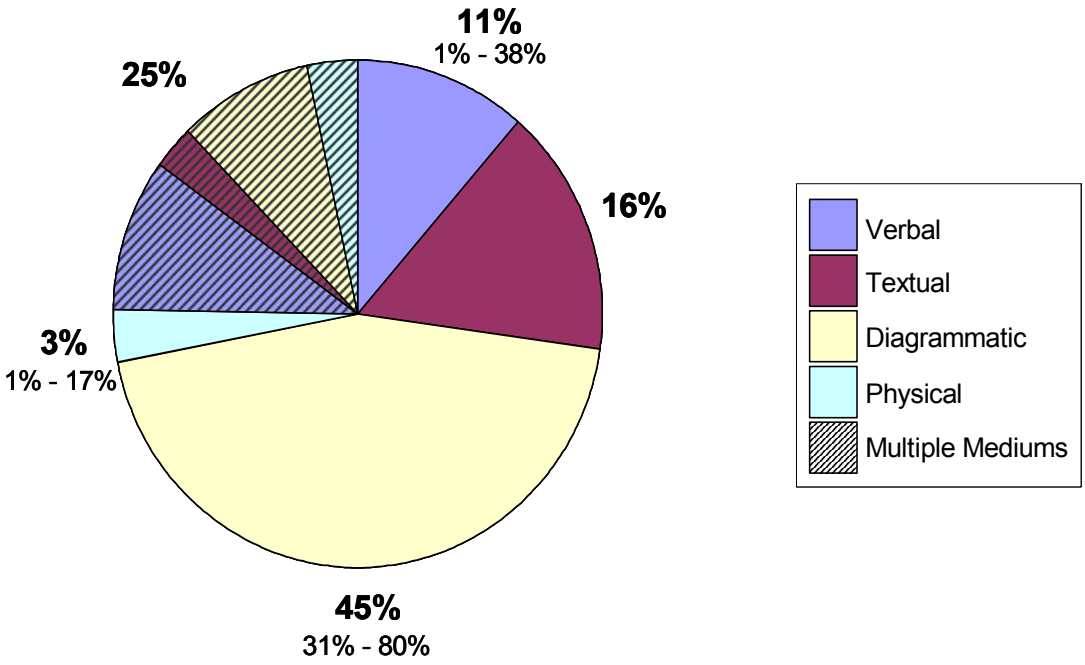


Figure 5-18 – Types of Information accessed by the innovation department

As expected, most information used in the innovation department is in diagrammatic form. This strongly correlates to the imaging and CAD software used as its carrier. Only 8% of the information use was in the form of physical or tangible information.

What is not captured by the data above is the quantity of information conveyed by each medium. It was observed that physical prototypes could convey more information, quickly and were often called upon in group sessions. Though it could be argued that these are the most formalised or realised forms of information, as a 3 dimensional medium, these are much more difficult at present to search and retrieve. It is believed that if effectively categorised and stored, the physical medium could be an extremely effective form of Stimuli.

5.4.4 Information streams

The information streams represented in Figure 5-19 show the typical relationships between sources, carriers and mediums of information.

	Source	Carrier	Type
Stream 1	Person	Face-to-Face Phone	Verbal
Stream 2	Internet Intranet Public Local	Word Processing Software Email CAD Imaging Software Paper Photo	Textual Diagram
Stream 3	Surrounding	Material	Physical

Figure 5-19 – Information Streams

Note: Depicted above are the most common streams of information.

Information stream 1 is perhaps exempt from improvement from this study, as conversational dialogue is dynamic and unable to be re-accessed. It may be that meeting minutes recording this dialogue could be a focus for further study or perhaps the project debriefing which is formalised electronically.

Information stream 2 has the most scope for search and reuse for creative Stimuli as much of it is stored electronically. Many of the documents in this stream are currently being used but not for creativity stimulation. Many of these could be reformatted and used as a stimulus library, in particular the data base of previous design projects.

Information stream 3 concerning physical prototypes, models and products of current and previous projects could be particularly interesting if it is shown that the most stimulating medium is physical. This could lead to cataloguing of the physical artefacts found around the office.

5.5 Task profile

As part of the information use audit, the task profiles were analysed addressing Objective F. Recorded within the supporting information of each snapshot was a project code linking the information use to a project database and was used to indicate the designer's workload (section 5.5.1). This database included project details such as, its current stage of the design process (section 5.5.2), the business sector of Crown in charge of the project (section 5.5.3), and what type of project it is (section 5.5.4). For more information see sections 5.1.4 & 5.1.5.

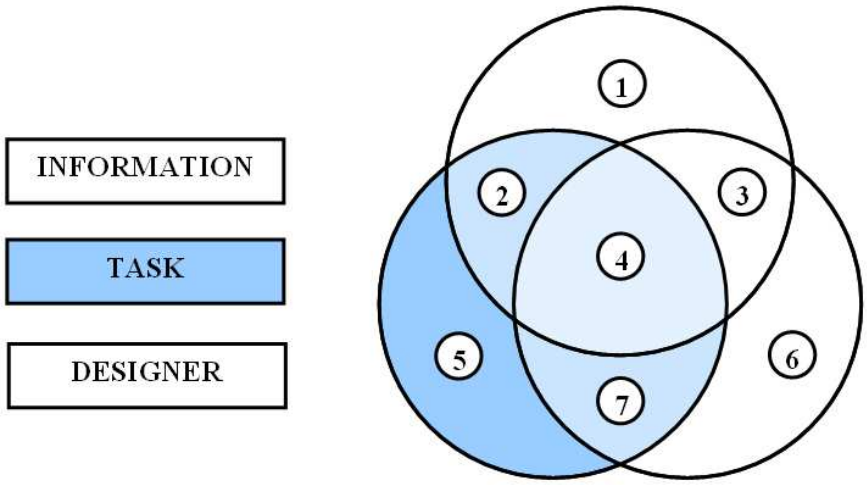


Figure 5-20 – Task dependant Major Area (see chapter 4)

This section will be considering many of the task related variables associated with one of the 3 Major Areas (see Figure 5-20). Each of the characteristics are analysed in order (process stage, business type, project type) in terms of their definition and their relationship to the information profiles (see section 5.4). These 'task' profiles will give a broader understanding of the task Major Area. Though the characteristics of this Major Area will not be further tested, the following profile will enable the results from descriptive study 2 to be looked at in a context of these and other possible influences.

5.5.1 Spread of project workload

The graph below shows the spread of each designers work over their live projects. The project ID represents the concentration of the work for each project, 1st being the designers priority project and 6th being the least priority. 'A' stands for administration tasks an 'U' as undefined.

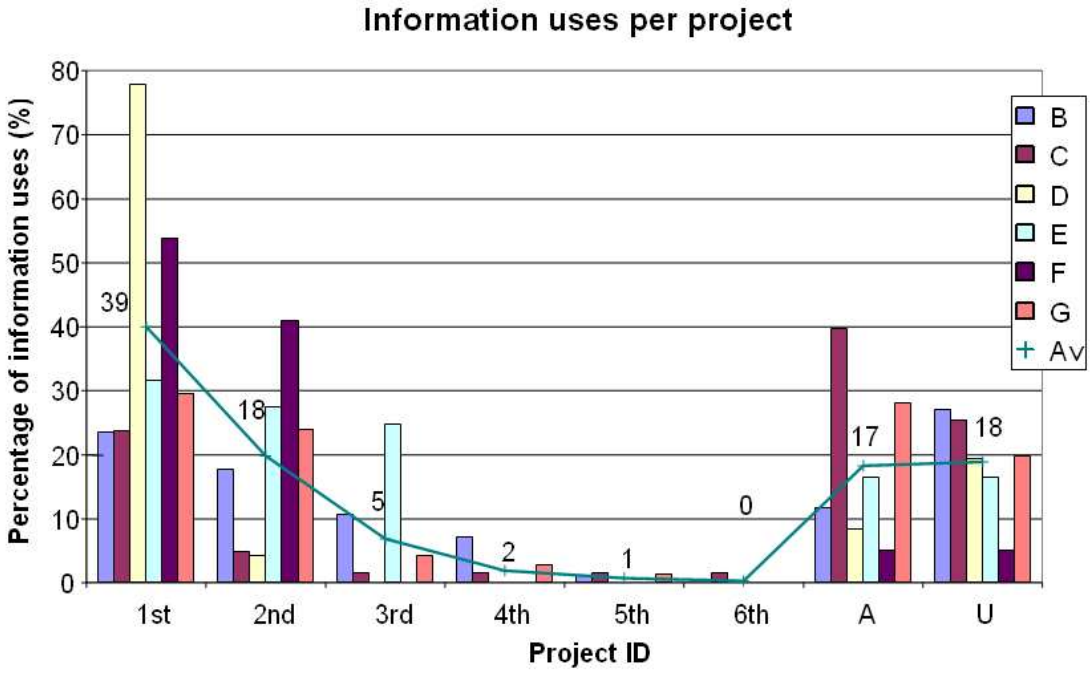


Figure 5-21 – Information uses per project of each designer

It can be seen that on average 5% of information uses are related to the 3rd priority project dropping to 2% to the 4th priority. One hypothesis may be that the designers with a more even spread of information uses over their projects will be subjected to more fresh Stimuli, therefore aiding creativity.

5.5.2 Information at each stage of the design process

It is believed by the author that the stage of the design process will have a large effect on the Stimuli being used to stimulate ideas. The following graphs (Figure 5-22) show how the data collated from information audit of all designers relates to the stage of the project being worked upon.

The information profiles at the two comparable design process stages are very similar. One notable difference is in the increased number of multiple uses which generally increased from the ideas stage to the conceptual stage. As the amount of face to face dialogue was not increased, the increase in multiple uses can be put down to the increased quantity and quality of documents and information. This would suggest that the communication in the concept phase is more efficient with more multi media information.

Projects in the concept stage produce more information uses from surrounding sources than projects in the ideas stage which would account for the high number of material information carriers. In contrast the ideas stage has more information uses carried by imaging software. This is also reflected in the information types where more physical information types are used in the concept stage possibly due to models, mock-ups and prototypes being made and discussed. In contrast the ideas stage contains more diagrammatic information. The decrease in sourcing from the internet moving from the ideas phase to the conceptual design phase would suggest a more, well defined task has been formed by this point.

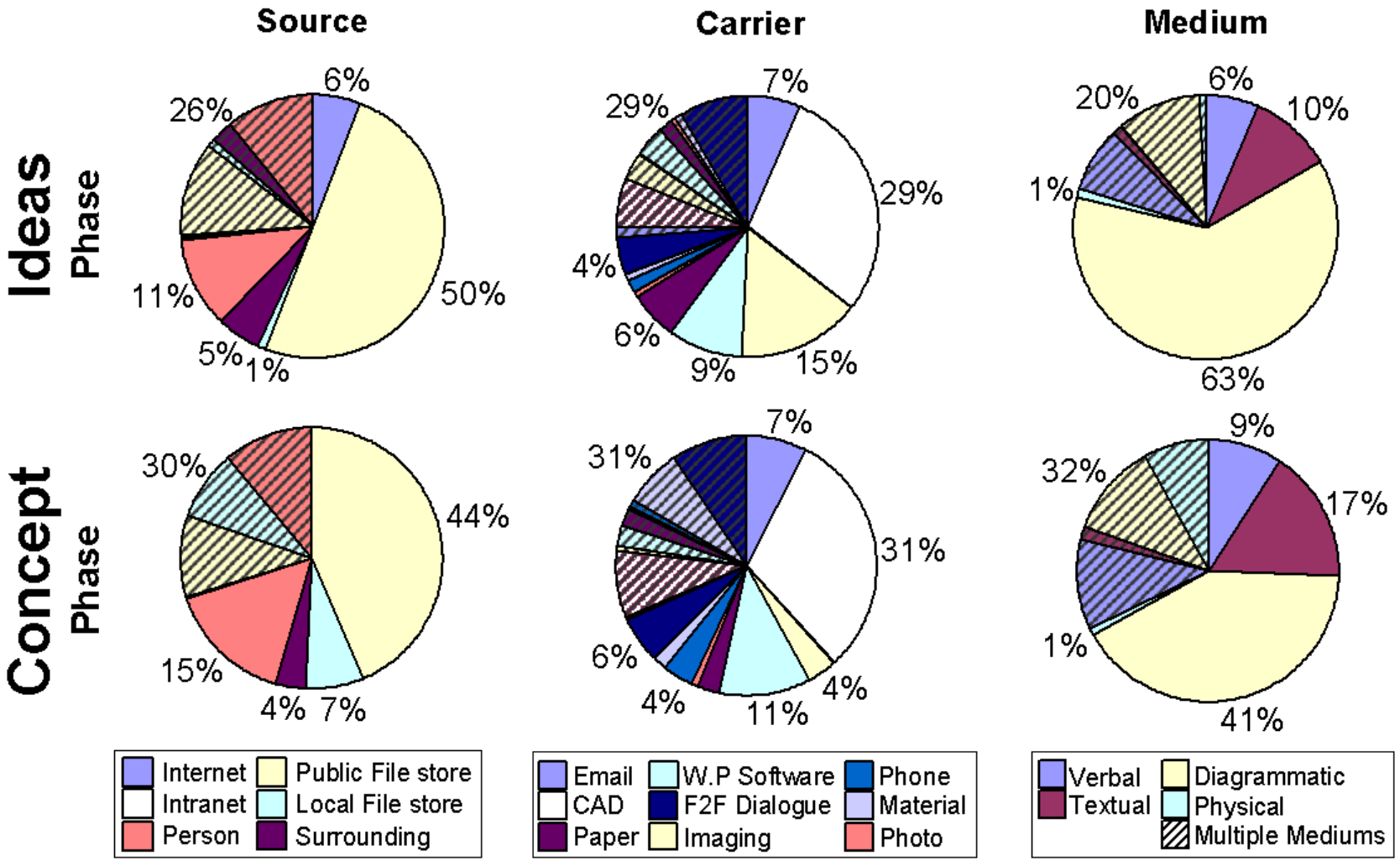


Figure 5-22 – Information accessed by members of the innovation department during the Ideas Stage and Concept Stage

5.5.3 Information for each business type

Crown Technologies has categorised their business areas by the product type produced as a result of a particular project (see section 5.1.4). The categories are:

Food Can: The part of the business responsible for designing, producing and selling food cans for products such as cat food, baked beans, soups etc. Project examples: Shaped cans, peal seams, novelty closures, re-sealable cans etc. The projects have a broad range of design concerns from, can function, manufacture and shaping to aesthetic design and marketing.

Speciality Metal: The part of the business responsible for designing, producing and selling bespoke metal containers for products such as bullets, gum, razors etc. The projects have very few dimensional and price constraints. The packaging uses known technology and capabilities to emboss and shape tins with high aesthetic value. The functionality is vital as the packaging is often designed for the user to keep and use rather than throw away.

Beverage Can: The part of the business responsible for designing, producing and selling beverage cans for products such as carbonated drinks, alcohol, coffee etc. Project examples: self heating/chilling cans, metal bottles, re-sealable cans etc. The projects have a broad range of design concerns from, can function, manufacture and shaping to aesthetic design and marketing.

Metal Closure: The part of the business responsible for designing, producing and selling metal closures or caps to fit on different glass bottles or jars of products such as drinks bottles, cooking sauces, jam jars etc. Typical projects would include various multifunction caps, tamper evident seals, and project Drizzle (detailed earlier in report). The projects are typically dimensionally constrained with many standard sizes, fitting, sealing and temper requirements to be adhered to.

Crown also has a relatively large Aerosol business which does not feature in the following graphs (Figure 5-24, Figure 5-25 & Figure 5-26) due to a lack of data.

It is believed by the author that the level of constraints is the major difference between the business types. The levels of technical constraints on each project are depicted by Figure 5-23. In terms of the spatial constraints on a product, speciality metals have far less than the metal closure division whose solutions have to adhere to many more standards in terms or dimensions, properties and a lower budget per unit. In terms of the creative idea generation, metal closures are more functionally constrained at point of brief.

Considering Figure 5-23, the creative solutions allow the design to break beyond the space defined by priori design decisions (Gero 2001) creating a new set of constraints. Differing levels of constraints varies the availability of innovative solutions. Creative leaps are needed in order to expand the priori design and thus making more innovative solutions possible.

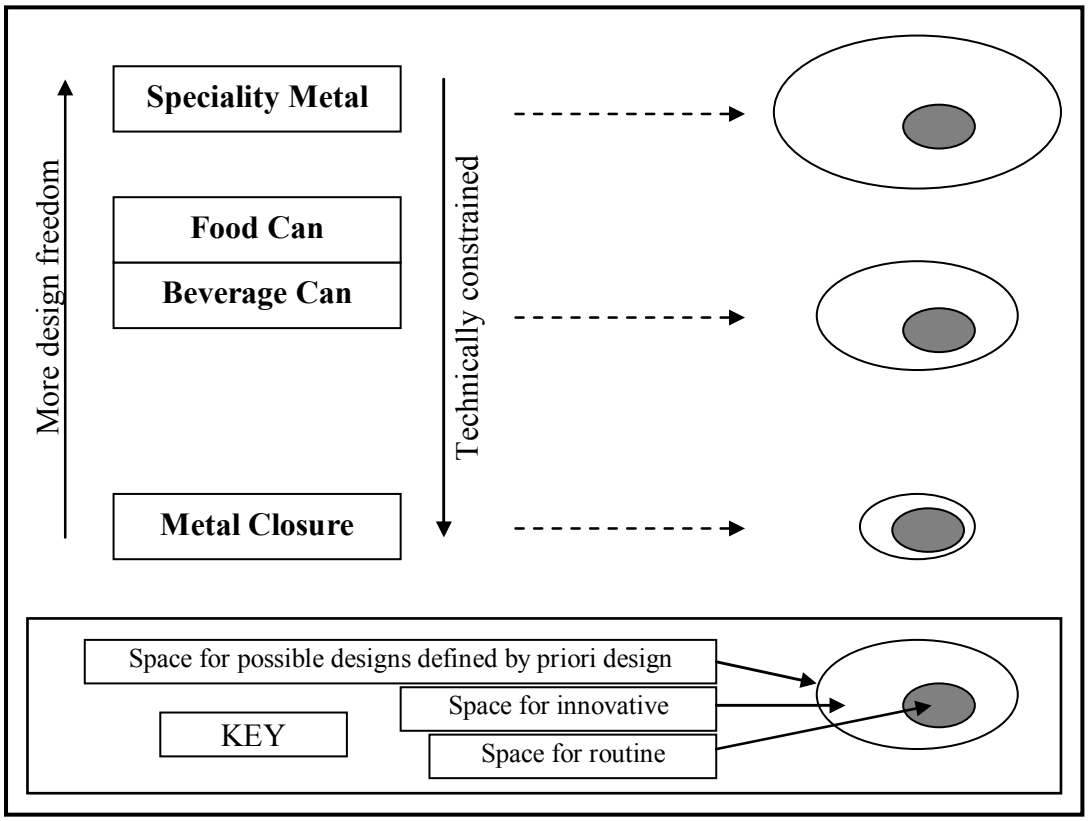


Figure 5-23 – Relationship between project constraint and business type

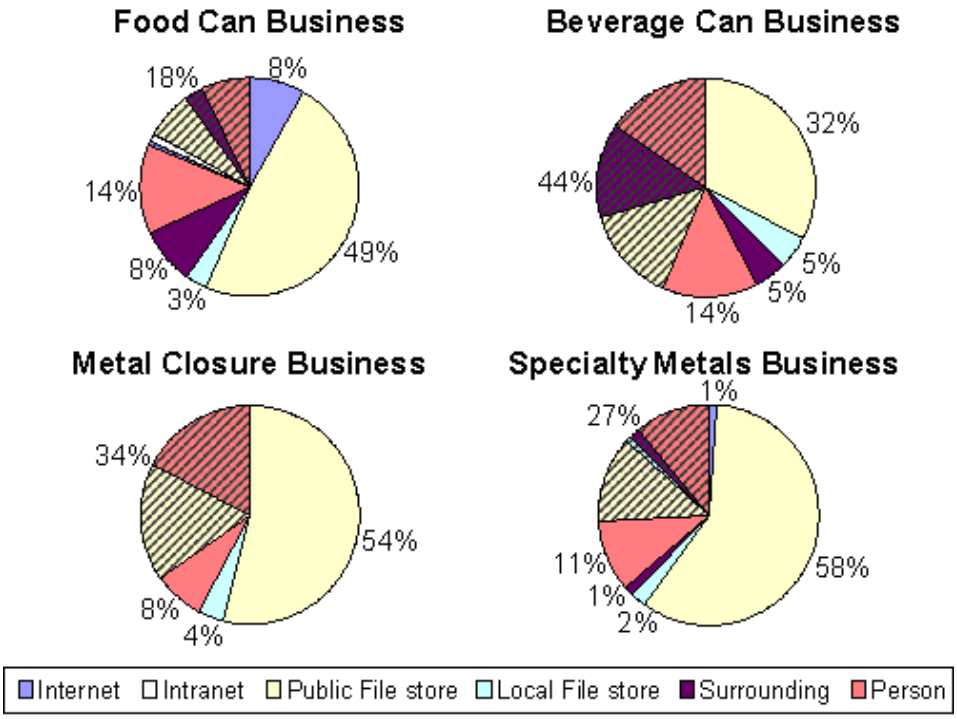


Figure 5-24 – Information Sources of innovation department for Business Type

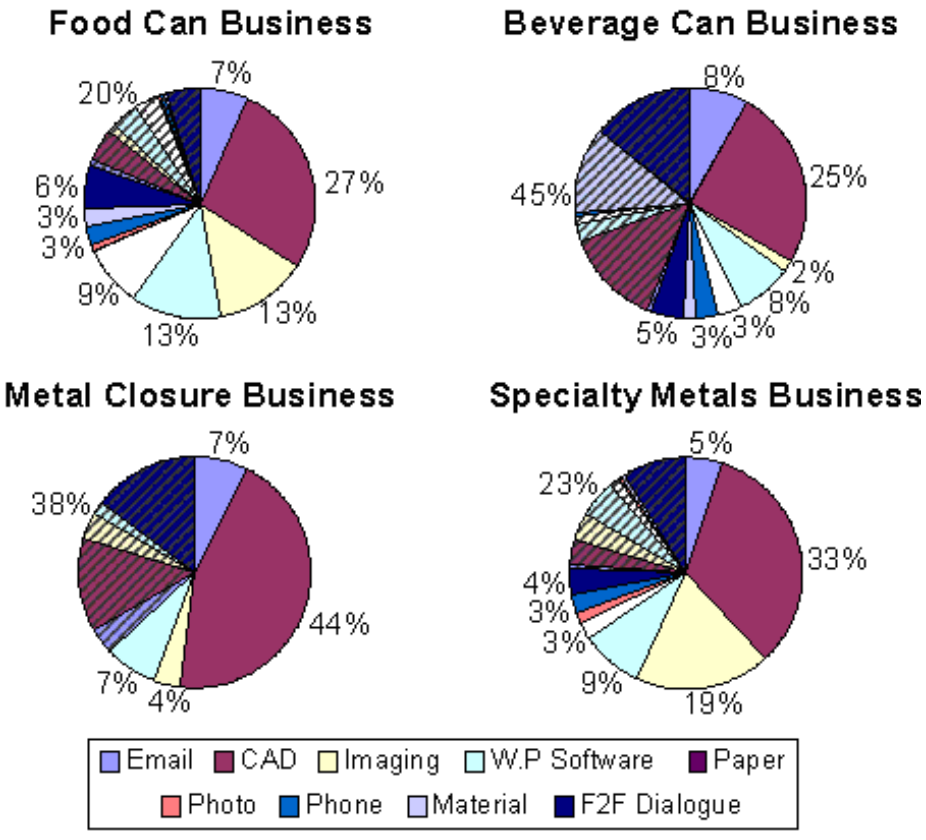


Figure 5-25 – Information Carriers of innovation department for Business Type

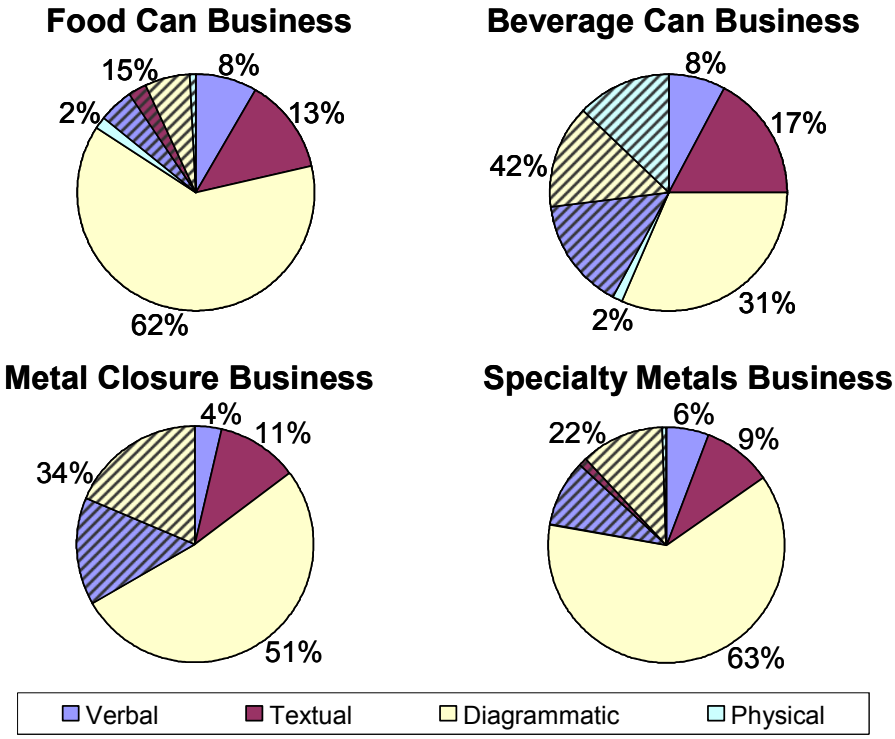


Figure 5-26 – Information Types of innovation department for Business Type

As expected, the metal closure business has the most information uses carried via CAD. This fits with the theory of the increased dimensional constraints as CAD could be easily used to check interferences and dimensional boundaries. It was also observed, as expected, that speciality metals projects carried more information via imaging software due to their aesthetic nature.

It can also be noticed that there are relatively large amounts of information uses for Beverage can projects carried by material (lot of functional design containing many samples) and large amounts of food can projects carried by paper (very conceptual projects based on aesthetics).

5.5.4 Information for each project type

Crown Technologies has categorised their projects by the sales strategy and relationship between customer and business for the particular product. The categories are:

Carrot: These projects arise from the recognition of the value a concept may have to a particular customer. Typically the product is developed to an advanced stage before revealing to the customer in order to enhance the 'WOW' factor.

Customer: These projects arise from a customer request for a particular solution or product with a particular consumer in mind. Typically the customer will work with the business, partake in regular reviews and be integral to decision making.

Generic: These projects have no particular customer in mind. The aim is to design a product that will suit a particular market need or make use of recent technological capabilities. The product is developed until it is deemed feasible or not before introducing to customers.

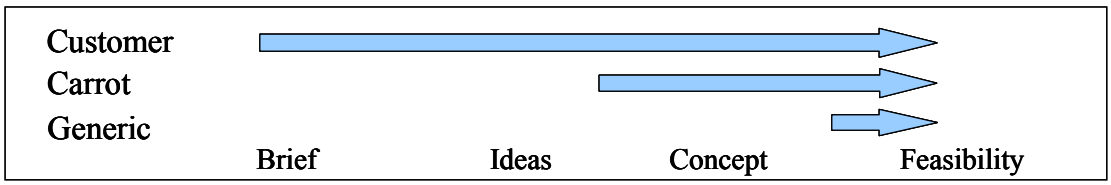


Figure 5-27 – Point of customer involvement

The results displayed in Figure 5-28, Figure 5-29 & Figure 5-30, complement back up the model of customer involvement shown in Figure 5-27. When assessing the information uses carried via imaging software (used for aesthetic design and essential to make the product look nice and saleable), Carrot projects have a score 19%, used to entice the customer, in comparison to 3% in Customer projects, when the customer has buy in from the beginning and need no additional selling. Another noticeable statistic is the high levels of physical information type in generic project. This could be related to prototypes used to test working principle.

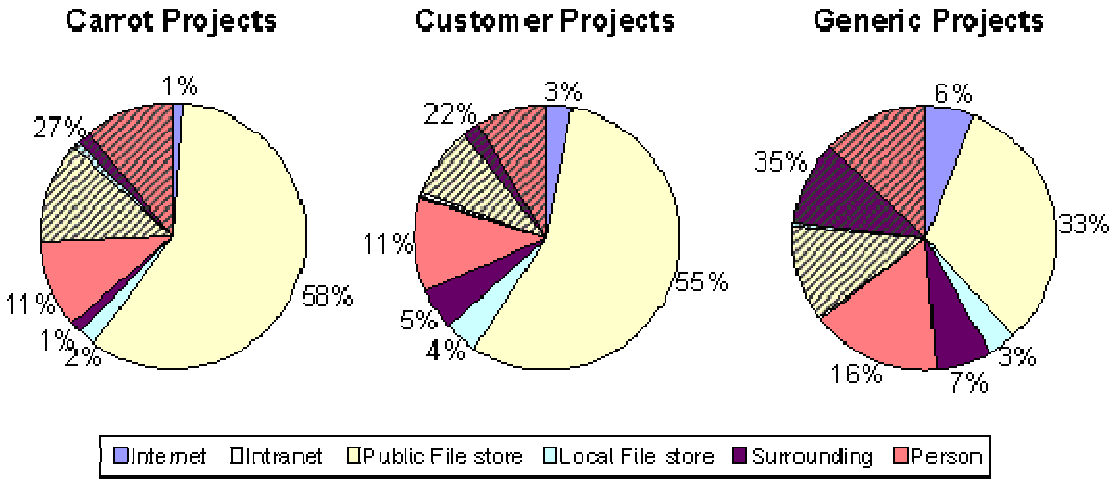


Figure 5-28 – Information Sources of innovation department for Project Type

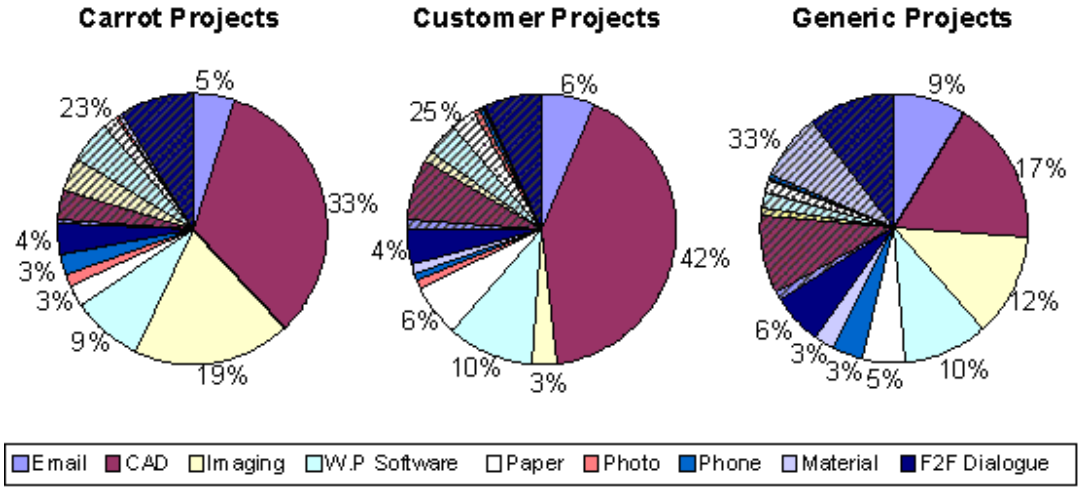


Figure 5-29 – Information Carriers of innovation department for Project Type

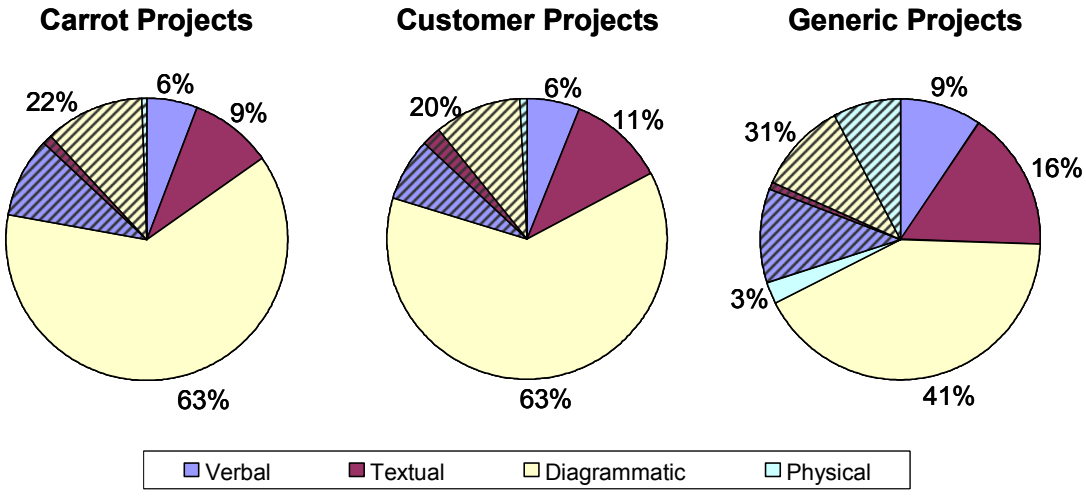


Figure 5-30 – Information Types of innovation department for Project Type

5.6 Designer profile

This section considers the information characteristics found in the designer Major Area shown in Figure 5-31, addressing Objective F. As there are a limited number of designers within the innovation department their influences cannot be experimentally controlled, however, these personal profiles will give further insight when analysing the results of future experimental work.

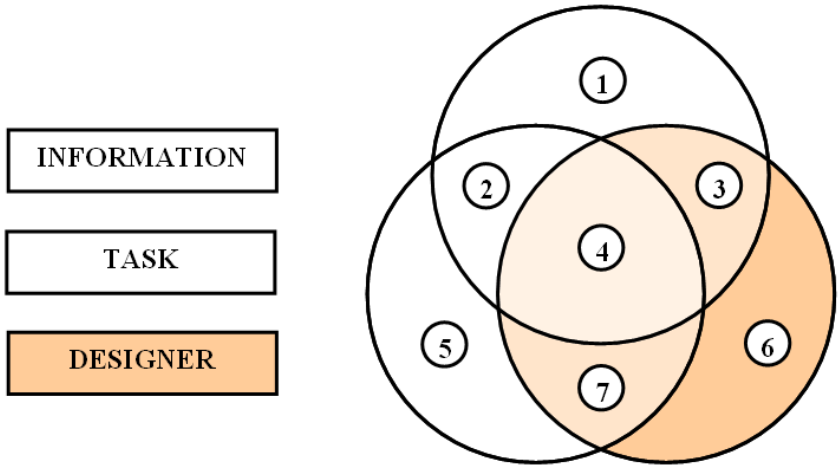


Figure 5-31 – Designer dependant Major Area (see chapter 4)

This section will provide some details regarding each designer's personal profiles regarding their information exposure (section 5.6.1), the interpersonal communication within the innovation department (section 5.6.2) and the location at which information uses occur (section 5.6.3).

5.6.1 Personal profile of information exposure

As part of the study, personal profiles of all the designers being studied in the innovation department were created. The team consisted of 4 product/industrial designers and 2 mechanical engineers (to degree level). Each audit assessed current and previous information exposure listed under broad headings such as previous jobs, qualifications, courses, hobbies and daily information resources. The audits were then made anonymous to enable reflection without personal judgments of the designers. Each information source was then ranked 0-4 in terms of: Design skill relevance, Job skill relevance, Industrial knowledge relevance, Job knowledge relevance, with reference to current job (see Table 5-3).

The Job headings in the following figures are in chronological order, where job 1 was the designer's previous job, as he job number increases it becomes less recent in the designers employment history. The data gathered was made more relevant to the research regarding creative stimulation by rating each of the information exposure categories to relevance to the skills and knowledge used as a designer. The ratings were decided through discussion between the designers and their interviewer.

	Skill	Knowledge
Generic	**Design Skill**: Relevance of the skills acquired in activity/vocation to the skill of creative design.	**Job Knowledge** – Relevance of information acquired in activity/vocation to the knowledge required for current position.
	Example: using CAD, sketching, maths.	Example: knowledge of: manufacturing processes, ergonomic, user tendencies, marketing etc.
Specific	**Job Skill** – Relevance of the skills acquired in activity/vocation to the skill of current position.	**Industry Knowledge** – Relevance of the information acquired in activity/vocation to the knowledge of packaging industry.
	Example: communication, time management, report writing etc.	Example: brand knowledge, specific manufacturing processes, supply chain, user appreciation, competition etc.

Table 5-3 – Information exposure categories

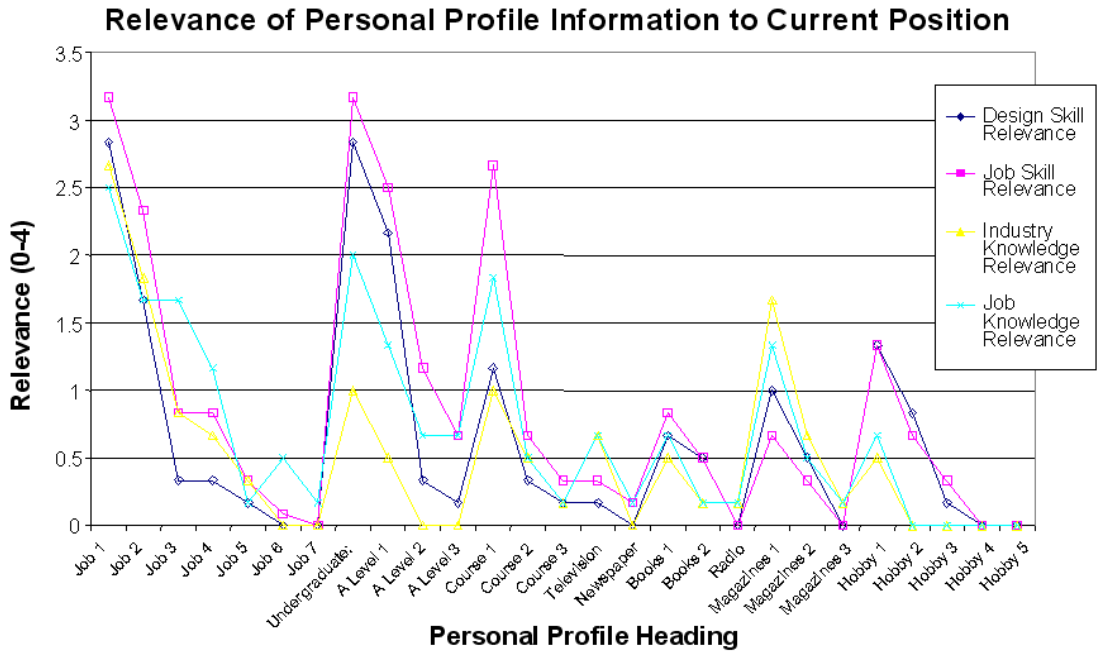


Figure 5-32 – Average of the team over Personal Profiles

From the above graph (Figure 5-32) it can be seen how, on average, the designers careers have become more and more specialised towards their current job in all respects. The undergraduate studies undertaken by each designer (product, industrial or engineering design in all cases) were judged to be very relevant to design in an innovation department. One interesting finding was that magazines are a useful source of information to the designers providing relatively large amounts of industrial knowledge. This was backed up by qualitative statements suggesting magazines are a favoured source of inspiration to designers.

5.6.2 Interpersonal conversation

The following graph (Figure 5-33) represents the information accessed by face to face dialogue from different designers within the innovation department and with external (Ext.) personnel. Communication with external personnel contributes to 45% of the overall discussions, suggesting that the project management style of the designers is more of an individual than group activity (concurred from personal experience). From within the innovation department communication is ranked from the different designer's perspective in terms of their most common (1st) to their least common (6th) converser. This shows that the members of the innovation department generally have roughly 30% of conversations with a particular designer within the innovation department. This could be due to the office layout or the business structure where some designers tent to specialise in the same areas.

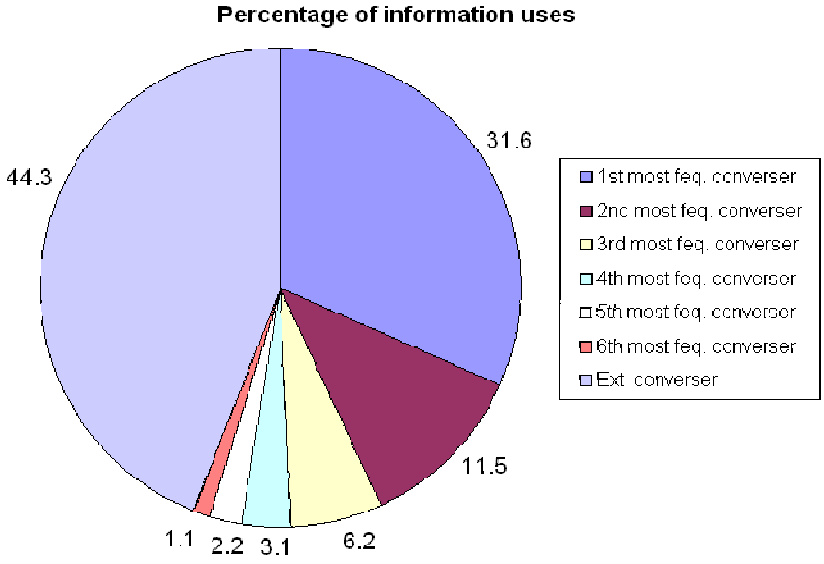
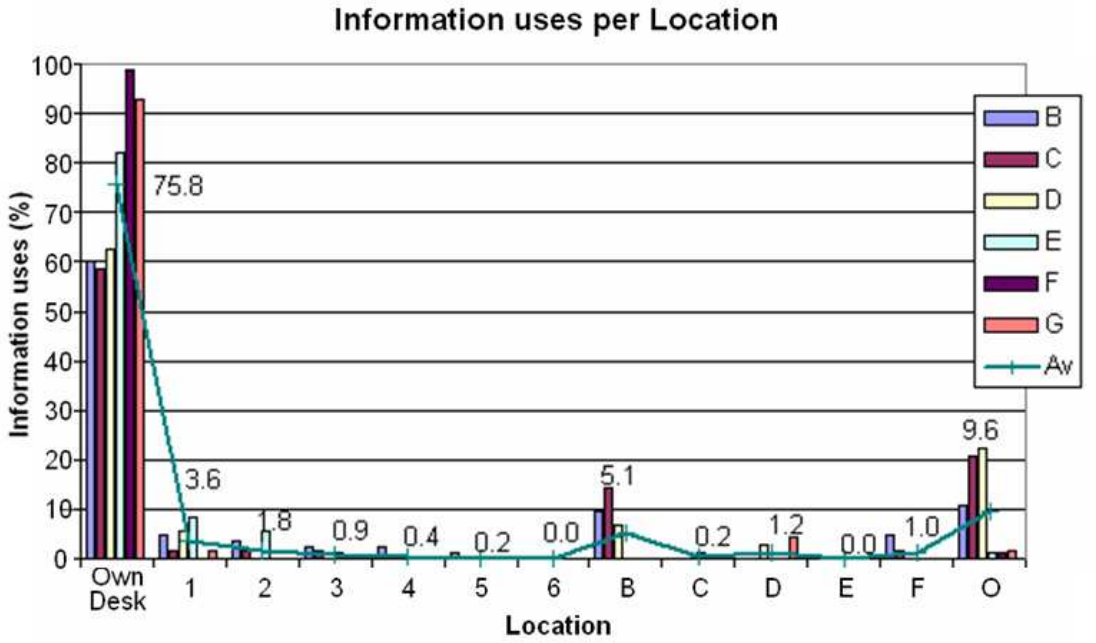


Figure 5-33 – Information uses per converser of each designer

It should also be noted that 26% of the above conversations took part between more than 3 people, usual comprising of group review meetings. It can be seen that on average only 3% of information uses are gained from conversations with the designers 4th most popular converser. This would suggest that the knowledge and creativity of the neighbouring designers is not being utilised to the full potential. One hypothesis may be that the designers with a more even spread of information uses over the other designers of the innovation department and external personnel will be subjected to more fresh Stimuli, therefore aiding creativity.

5.6.3 Location breakdown

The following graph represents the rough breakdown of the locations at which the designers access and use information. As expected, most of the time is spent at each designers own work station or 'own desk'. The following locations represented by 1-6 are the other designer's desks in the innovation department, 1 being the most favoured desk to visit, 6 being the least. This should correlate closely to the conversation between the designers. The other locations represented by B-F, represent other areas of the innovation department.



B – Design Studio	C – Lounge	D – Workshop
E – Archive	F - Refreshments	O – Out of Department

Figure 5-34 – Information uses per location of each designer

While the designers generally stay at their own desks whilst in the department they spend 10% on average of their time out of the office which is a very high percentage. The design studio (B) was well utilised and was home to the majority of the multiple conversations. Perhaps an under used resource is the archives room providing no recorded occurrences. This is an area of much information and potential Stimuli all from previous solutions to design problems.

From the above graph it is clear that the designers spend most of there time at their own desks, with a significant amount of time spent in the design studio where brainstorming and group meetings take place. It would therefore be necessary to target these areas when implementing this research or to encourage behavioural changes to the designers, encouraging time to be spent in other locations.

5.7 Summary and discussion

This observational study draws quantitative figures of information use from all dimensions under study. Participation action research was conducted, working as project manager for an innovation project along with participating in team activities. This gave the author a more in-depth knowledge to both gather and analyse the data captured. A snapshot of a single designer's information use was observed and recorded using a purposefully constructed and modified recording chart.

In order to fulfil Objective F the information Major Area was assessed in section 5.4. The results of the audit revealed that the majority of information use sources were accessed electronically on the public or shared hard drives which concurred closely with Collet's (2004) findings. It was also observed that the majority of information uses were carried by CAD, imaging software and office software; other substantial carriers included email and face-to-face dialogue. From the participation research it was realised that documents containing information carried by CAD and imaging software were formalised and summarised in the office software. Over 50% of information uses were in a diagrammatic medium emphasising how abstract diagrammatic representation is at the heart of early stages of design. The stimulus proposed to designers should thus reflect these results.

The task profiles were also monitored to address Objective F. It was observed that 39% of designer's information uses are directed at their most worked upon project, followed by 18% on their second. Nearly all none-administrative information uses were directed at the ideas and concept stages of the innovation project. The conceptual design stage uses a wider spectrum of information media in comparison to the ideas phase which comprises of roughly 75% of uses in a diagrammatic medium. It is thought extremely important to control the stage in which the Stimuli are tested due to the drastically different levels of constraints. It was also observed that the metal closures projects were perhaps the most different in nature and should be avoided if possible. Also, customer and carrot projects had remarkably similar information profiles and should be used in preference to generic projects.

To fulfil Objective F the designers' profiles were assessed. It was shown that the mechanism by which the stimulus interacts with the designer (pushed to the designers) makes up only ~10% of the information uses. The various designers varied quite substantially in terms of their conversation profiles and location profiles. It was also observed that the personal exposure profiles were quite different. It was found hobbies were a source of information exposure useful for designer skills and magazines relevant to the designer knowledge were required. More experienced designers should be used in preference as the trainee designers performed noticeably different activities.

With an understanding of information use within the case company's innovation department, a prescriptive study is to be conducted to investigate a distinct knowledge gap and develop a creativity support tool taking advantage of findings within this chapter.

6 *Prescriptive study – Impact model for design support*

In the previous chapters, a broad range of literature has been reviewed, and the fundamental theory underpinning this research regarding Outer Stimuli on idea generation was presented. In order to validate such theory in an industrial setting, creativity tools provide both a benefit to the case company and will form a good point of comparison. This chapter details the third stage of the methodology, the theoretically based prescriptive study. The role of the prescriptive study stage (Blessing and Chakrabarti 1999) is:

- To develop support in a systematic way.
- To evaluate the support with respect to in-built functionality, consistency, etc.
- To develop an impact model or theory, based on the reference model or theory from the Descriptive Study stage, describing the expected improved situation.

The above points are dealt with by first reviewing current creativity support tools and their underlying theory (section 6.1). A proposed approach, which will be embodied as a tool called the Information Management Creative Stimuli (IMCS) tool is then positioned relative to other tools within a matrix, narrowing down the area in which it will impact. The subsequent section (6.2) will review other competing tools from the matrix, and at a theoretical level will unveil a promising gap in the knowledge where this research and tool is to be pitched, addressing Objective E. The Information Management Creative Stimuli (IMCS) tool is then discussed in more detail, describing a potential embodiment along with the modification made for simulation purposes (section 6.3).

A research hypothesis regarding the types of Stimuli proposed by the various tools is described (section 6.4). The final section will present a summary, highlighting the main points by which the research method of descriptive study 2 in the following chapter is to be created (chapter 7).

6.1 Creativity support tools

It could be argued that a creativity support tool should aid a designer during any phase of the creative process, either; as a task framing tool during the analysis phase; as an idea generation tool during the generation phase; or as a selection or evaluation tool in the evaluation phase. This research will concentrate on the generation tools, though there are many different viewpoints from literature by which these tools can be categorised.

6.1.1 Categorising by interface

In computer science, creativity support systems (CSS) are often defined by the type of interaction with the user (Lubart 2005), working as either a:

Nanny: encouraging creativity by monitoring and supporting the individual,
Pen-pal: facilitating collaborative interaction,
Coach: providing information by which to form analogy, also proposing tool/techniques, or,
Colleague: contributing ideas and solutions of its own.

The CSS acting as a Nanny or Pen-pal are perhaps easily achievable with current knowledge and technology. Advanced computer based CSS acting as colleagues are the most ambitious. It could be argued that certain constraint modellers aid in this way as they can propose different formations given the constraints and goal states. However, for typical design problems, tasks are often open ended and poorly defined with unknown goal states. The IMCS tool proposed at the end of this chapter will work as a 'coach' increasing the designer's creativity by expanding their access to information (Giampà *et al.* 2004).

6.1.2 Categorising by cognition

In another categorisation scheme, tools are judged by the mental process that is stimulated (Finke *et al.* 1992; Massetti 1996). In this scheme, tools are classed as either:

Generative, which aids lateral/divergent thinking to produce new ideas, or, **Explorative**, which aids linear/convergent thinking to develop solutions.

Though the IMCS tool is to be considered generative, it may also be useful for the linear development of concepts.

Running parallel to this categorisation scheme is that proposing the creativity support tools can aid creativity at three different levels, at a skill level, at a procedural or methodical level, or at a stimulus level (Chakrabarti 2006). A similar scheme was also used by the author when categorising by mechanism (see section 6.1.4), positioning the IMCS tool at the latter, 'stimuli' level.

6.1.3 The Zusman (1999) categorisation

The Zusman (1999) categorisation scheme provides a far more comprehensive overview for creativity support, though there is no distinction made between tools, methods and techniques. Within a matrix of comparable tools, the following seven categories are proposed, describing the creativity support approaches that the tools techniques and methods use:

1. Conditioning/motivating/organising: The techniques, procedures and/or special conditions and means belonging to this group help create an environment that facilitates the removal of various mental blocks, unleashes natural creativity, etc.
2. Randomisation: Since psychological inertia usually keeps an individual "inside the box" of his/her paradigms/perceptions/assumptions, forcing an individual to make more random attempts to solve a difficult problem were found to be very helpful. Randomisation makes the search more chaotic.
3. Focusing: Many people have difficulty with random idea generation when no guidelines or focusing steps or subjects are offered. Special focusing techniques are used to help an individual focus on one issue at a time and avoid frustration. Focusing elements (steps) may be presented with or without any particular order (random focusing).
4. Systems: A system contains a set of focusing or random steps to be followed in a specific order.

5. Pointed: These offer single or multi-step recommendations following a pre-determined, promising direction. This direction may be identified as useful based on intuition, experience or documented knowledge.

6. Evolutionarily directed: These offer directions according to fundamental patterns of evolution.

7. Innovation knowledge-base: These utilise structured knowledge derived from the past human innovation experience.

Table 6-1 shows a selected sample of the original matrix (Zusman and Zlotin 1999). The tools, in the first column are related to 7 different approaches by which they support creativity. In addition to the original matrix, the Information Management Creative Stimuli (IMCS) tool to be proposed at the end of this chapter is placed at the bottom of the table.

Tool/Method/Technique	Creativity support approach						
	1	2	3	4	5	6	7
Random input		X	X				
Problem reversal				X	X		
Lateral Thinking			X	X	X		
Brainstorming		X		X			
Forced Analogy		X	X				
Attribute Listing			X				
Mind Maps			X	X			
Storyboarding	X		X	X			
Synectics			X	X	X		
Role playing		X					
Fishbone diagram			X	X	X		
Redefining a problem/opportunity		X		X			
Delphi	X			X			
Basadur Simplex process				X			
TRIZ Contradiction Table and 40 Innovation Principles	X		X	X	X	X	X
TRIZ Problem Formulation	X		X	X	X		
TRIZ Substance-Field Analysis	X		X	X	X		
TRIZ 76 Standard Solutions	X		X	X	X	X	X
TRIZ System of Operators	X		X	X	X	X	X
Information Management Creative Stimuli (IMCS) tool	**X**				**X**		**X**

Table 6-1 – Creativity tools matrix

6.1.4 Categorising by mechanism

To further analyse the tools, techniques and methods from Table 6-1, the author proposes a categorisation scheme with some simple abstracted diagrams showing the mechanism by which each type of creativity tool works. The first of the creativity tools aid problem re-definition and opportunity analysis and have been termed 'Creative Analysis' tools. These tools essentially encourage exploratory thinking within the problem space, where the emphasis is not on forming a solution but redefining the problem (mechanism described in Figure 6-1).

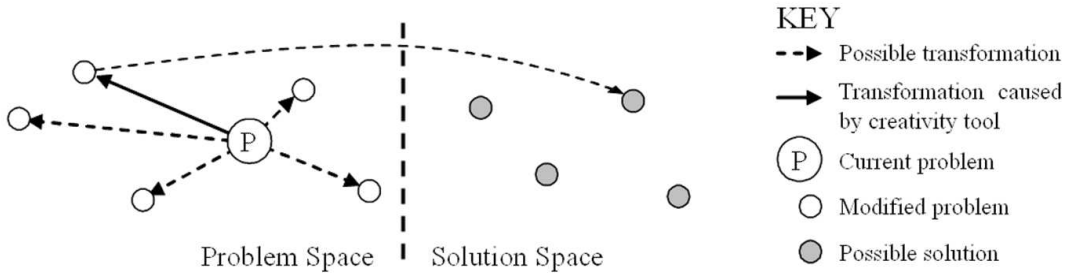


Figure 6-1 – Mechanism for creative analysis tools

Typical creative analysis tools would include: 'Problem reversal', 'Synectics', 'Redefining a problem/opportunity', 'TRIZ problem formulation' and 'TRIZ system operators' which assesses the system being worked on in terms of its time line and systems level. This allows the designer to find alternative problems at the macro and micro level, and in the past and future.

The second mechanism is termed the 'Creative Thinking' tool. These tools aid the designer by encouraging the exploration of the solution space until they are illuminated with a valid solution. This moving from a problem to a solution is depicted within Figure 6-2. To tie this to the earlier theory of creative idea generation, these tools aid the Retrieval of Inner information in 'I' type creative idea generation (section 3.3.2).

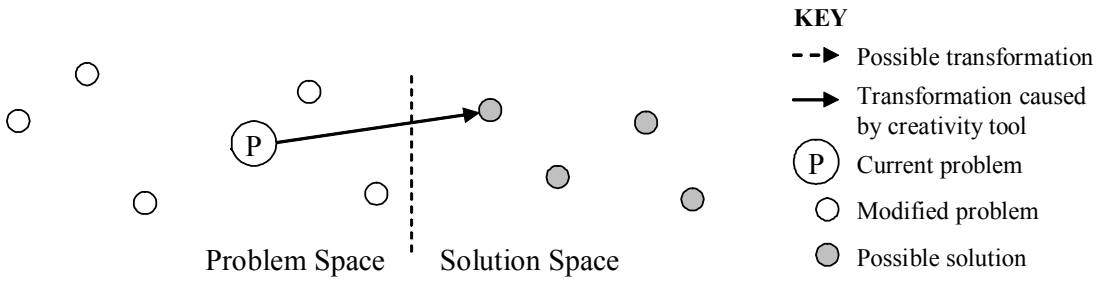


Figure 6-2 – Mechanism for creative thinking tools

Typical creative thinking tools would include: 'Brainstorming', 'Mind maps', 'Storyboarding', '6 Hats' and 'Role playing'.

The final category is the 'Creative Stimulus' tool category. These tools simply propose some stimulus as a new start point by which to relate the problem to. This mechanism is shown simply in Figure 6-3, and complements the cognitive mechanism for 'O' type creative idea generation in section 3.3.2, using surrounding information to produce a creative idea through association.

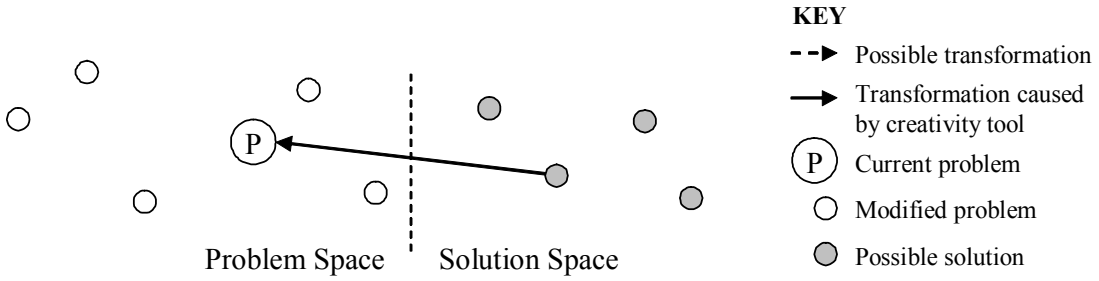


Figure 6-3 – Mechanism for creative stimuli tools

Typical creative Stimuli tools are in italics in Table 6-1 and include: 'Random inputs', 'TRIZ 76 standard solutions', 'Forced analogy', the 'IMCS' tool and the 'TRIZ Contradiction matrix and 40 principles' – A matrix by which to prompt principles that have solved the same problem (when abstracted to a certain degree) in previous patents (Altshuller 1999).

6.2 Identifying a knowledge gap

In the previous section, a classification scheme was proposed differentiating creative Stimuli tools (Figure 6-3) from other creativity support tools. These types of tools have been singled out, as they provide a useful mean of testing various types of Stimuli in an industrial context. Within this creative Stimuli tools category is the IMCS tool proposed in section 6.3. It is now important to analyse these tools more thoroughly in order to understand exactly how they differ. It is at this level; a gap in knowledge can be recognised; identifying a new and potentially useful type of Stimuli, which described in the next section.

6.2.1 Matrix of creative stimulus

There are few categorisation schemes for the types of creative stimulus within literature. Previous related schemes have described the types of stimulus in terms of function, behaviour, form and knowledge entities (Benami and Jin 2002). Others have categorised the stimulus as heterogeneous or homogeneous (Nijstad *et al.* 2002) with respect to the previous idea produced. The categorisation scheme first introduced in the introductory chapter (section 1.2.2) was based on related literature and the potential of Internally generated Stimuli realised during the descriptive study (chapter 5). The categorisation comprises of a 2x2 matrix (Table 6-2) constructed from the following two categories:

Source: where the Stimuli are drawn from. This can either be Internal or External to the industrial domain in which the task is set.
Retrieval: how specific the retrieval mechanism is to the task. The Stimuli can either be retrieved by Random, or, Guided by an abstracted framework making it more affective (theoretically) to the task at hand.

		Retrieval	
		Random	Guided
Source	External	A	B
	Internal	C	D

Table 6-2 – Matrix of creative stimulus

6.2.2 Knowledge gap

It is very common for creative Stimuli tools to prompt Stimuli gained from Sources External to the domain. However, none of the research from the literature reviewed, nor any commercial creativity tools have considered the potential of Stimuli generated Internal to the industrial domain (Amabile 1982; Santanen *et al.* 2004; Santanen and de Vreede 2004). The following research aim has been constructed to address the following gap in knowledge.

*This research will analyse the potential of **stimuli** generated from **Internal information** sources from within the industrial domain in which the design task was set*

The potential of Internally generated Stimuli will be validated through the performance of creative Stimuli tools in matrix positions C and D (Table 6-2) relative to the Externally generated creative Stimuli tools in positions A and C (Table 6-2). Each of these tools is further detailed in section 6.2.3 with particular emphasis on the explanation of the 'Retrieval' criterion shown in the matrix (Table 6-2).

6.2.3 Creativity tools within the matrix

The four different types of creative Stimuli tools used to validate the potential of Internally generated Stimuli will now be detailed along with descriptions of how they were presented in the experimental work in chapter 7 (reference to Table 6-2):

Type A creative stimuli tools

Type A tools draw on Random Stimuli from Sources External to the industrial domain in which the problem is set. From the Zusman et al. (1999) matrix, typical tools would include 'serendipity', 'forced analogy', 'relational words' and most representative 'random input'. To simulate the Type A creative Stimuli tool during the experiments, images were taken randomly from a popular online image bank and displayed singularly on electronic slides.

Type B creative stimuli tools

Type B tools are intelligently Guided to stimulus from Sources External to the industrial domain in which the problem is set. This type of tool was made popular by TRIZ, the theory of inventive problem solving (Altshuller 1999). However, there are several other creative Stimuli tools that use Guided stimulus Retrieval such as FuncSION (Chakrabarti and Tang 1996) and Animal Crackers (Grossman and Lloyd 2006). To simulate Type B creative Stimuli tool the TRIZ contradiction matrix will be used as an example. Here 40 000 patents were categorised by the design contradiction[1] which they solved without compromise. A pattern emerged in the form of the contradiction matrix, where it is proposed every new problem can be broken down to its contradiction and the historically appropriate solution principles[2] can be extracted from the matrix and used as stimulus.

Type C creative stimuli tools

The theoretical Type C tool draws Random Stimuli Internal to the industrial domain in which the task was set. Currently no official Type C tools exist, though they are commonly simulated naturally through designer's behaviour. It is common to look at previous designs, particularly through catalogues and prototypes from within the domain. In order to represent this type of tool, random concepts were selected from within the huge repository of previous design projects stored by the case company and used as Stimuli.

Type D creative stimuli tools

The theoretical Type D tools are intelligently Guided to Stimuli Internal to the industrial domain in which the task was set. Though currently no official Type D tools exist, they are embodied by the IMCS tool presented in the following section.

[1] Design contradiction – when 2 design requirements conflict (one improves the other worsens)

[2] Solution principles – the general inventive principle behind each solved contradiction.

6.3 Information Management Creative Stimuli (IMCS) tool

The IMCS tool comprises of three dimensions, a *search* dimension, a *return* dimension and a *store* dimension (see Figure 6-4). Though the tool was manually simulated using the principles behind the search, store and retrieve dimensions, an automated version is easily achievable requiring minimal maintenance/administration from designers.

Comparable with the TRIZ contradiction matrix, which uses abstracted design contradictions to link the current problem to previous problems, the IMCS tool creates this link by comparing 'musts' and 'desirables' from the design specifications at the host company. Though there are several methods by which to recall Stimuli in an intelligent, Guided manner, the method detailed below is one example providing a repeatable simulation of a Type D tool and fulfils the research Objective E.

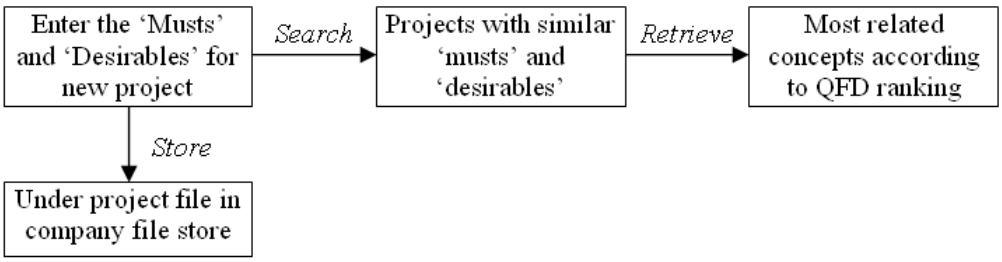


Figure 6-4 – Customised Search, Retrieve and Store approach of IMCS tool

6.3.1 The search dimension

New project brief documents (Figure 6-6) are constructed from standard brief templates (Figure 6-5). On the construction of a new brief, musts and desirables are entered and linked to pre defined categories. The IMCS program then searches through the project files to find other project briefs containing the most accurately matched musts and desirables. For simulation purposes this was done by key word searching through the project briefs (Figure 6-7).

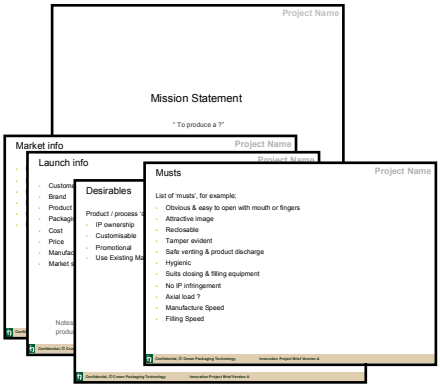


Figure 6-5 – Brief templates

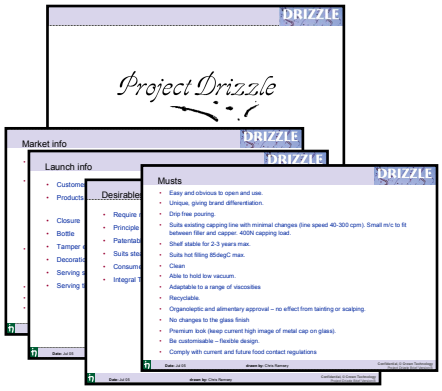


Figure 6-6 – New briefs

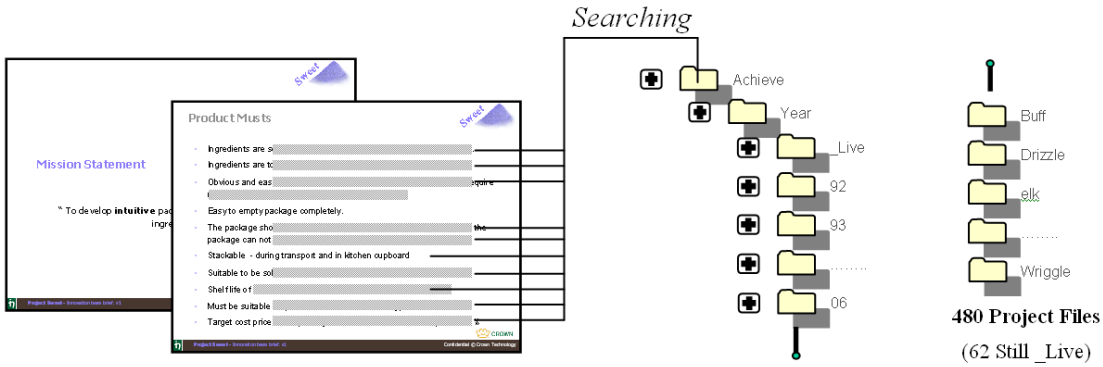


Figure 6-7 – Searching for related project briefs

6.3.2 The retrieve dimension

Once the projects are identified from the search they are ranked as to how many musts and desirables were matched. As a secondary ranking, relatively rare requirements (such as 'must enable one hand opening') are ranked more highly than those which are more common (such as 'must be hygienic'). Once the most relevant projects are identified the IMCS tool can return concepts from within the project files. The selected concepts from each project can be selected randomly, or linked to the QFD[1] (Cross 2000) files ranking how well each concept performed against the musts and desirables. This was used whenever a QFD file was present within the project folder. Concepts were returned in the form of a single slide (Figure 6-8).

[1] QFD – Quality function deployment, used for evaluation and selection

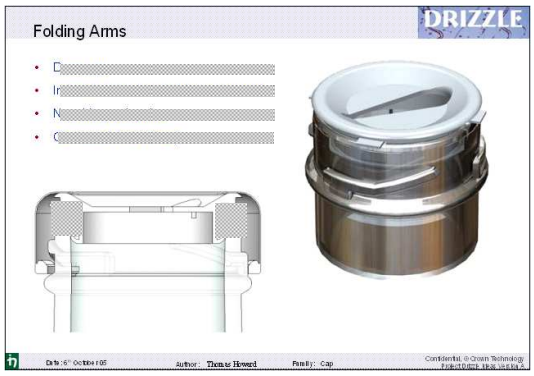


Figure 6-8 – Example concept returned as stimulus from IMCS tool

6.3.3 The store dimension

In order to make the IMCS tool self populating and expanding, the new project briefs and concepts must be stored onto the system ready for retrieval at a later date. The brief must therefore be added to its project file and its musts and desirables categorised by the higher level structure. In order to do this, the musts and desirables are entered by free description and ten linked via drop-down menu to the higher level heading (Figure 6-9) which is used for the search function. The concepts designed for each new project are saved under a consistent file name and stored within the project file along with any QFD analysis files.

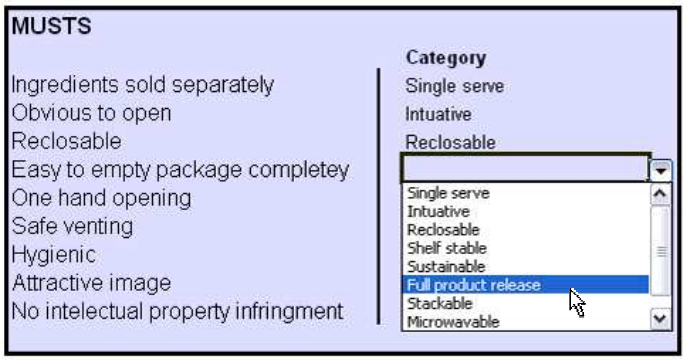


Figure 6-9 – Linking musts to a higher level category

6.3.4 Implementing the IMCS tool commercially

The Information Management Creative Stimuli (IMCS) tool relies on several conditions, all of which were fulfilled by the case company. Firstly, the company must have a consistent and standard design process. Secondly, the documents

containing the project brief, the designed ideas and concepts and must be consistently and appropriately named and must be stored electronically and logically.

There is also potential for further developments of the IMCS tool. Within the Design Information and Knowledge group under which the author researches, there is a vision of immortal information, in which no information is lost or made unavailable. Within the case company virtually every idea is already being recorded, however, no system is yet put in place for the retrieval of the informally recorded ideas. As the field of information management progresses this may become more realisable as information is more effectively managed.

6.4 Research hypothesis

From the theory presented so far there is an interesting contradiction in the relative position of the research. From theory proposed in chapter 2 it is suggested that creative design outputs are dependent on creative ideas at differing points of the design process. In chapter 3 it is proposed that creative ideas can be stimulated from External Sources, only if the stimulus is both Un-Apparent and Relevant. This idea of Un-Apparent having a direct link to creative idea generation poses a problem. The closer (in terms of levels of abstraction) the stimulus is to the domain and task, the less Un-Apparent it will become, therefore becoming less helpful to creativity. So why would an information management system for creative Stimuli be useful?

This question can be simply answered in term of information Relevance. It is proposed that Stimuli tools from categories A and B (Table 6-2) will produce ideas that are more Un-Obvious than tools C and D, respectively. However, it is also proposed that tools C and D will produced a higher number of Appropriate ideas due to the Stimuli being Relevant more often. In simple graphical terms, Figure 6-10 presents the hypothesis that on average, tools C and D will outperform tools A and B respectively. This is because they will prompt more Relevant Stimuli, producing more (quantity) creative ideas.

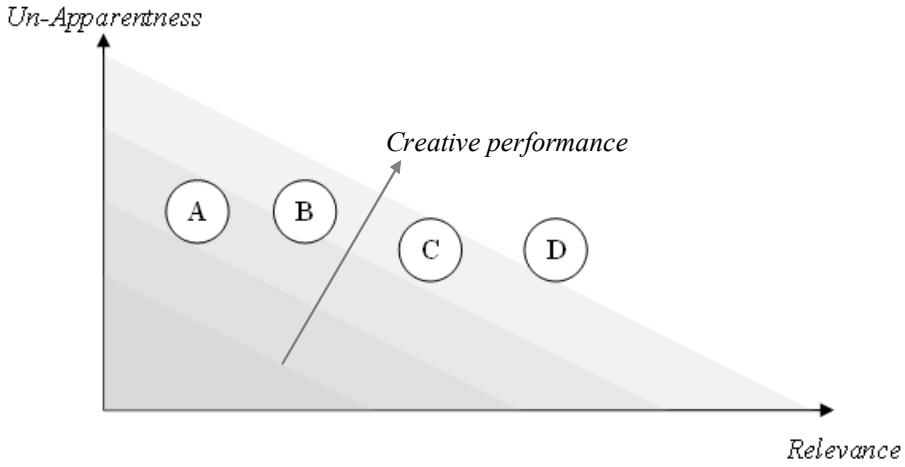


Figure 6-10 – Un-Apparentness-Relevance ratio of average stimuli produced by the various tools

Figure 6-10 which shows the distinct bands describing a hypothesised increase in creative performance from left to right. These two axes are the variables of characteristic 1, central to the Major Areas influencing creative stimulation proposed in chapter 4. In terms of the Retrieval of Stimuli, whether Guided or Random, it is hypothesised that stimulus retrieved by the Guided method will be on average more Relevant and thus will more often stimulate creative ideas than Stimuli produced randomly. However, in this case it is hypothesised that Retrieval criterion will be less influential than the Source of the Stimuli. This is depicted in Figure 6-10 which shows that type C and D tools from Internal Sources are positioned in higher band than the External Source tools types C and D; and will thus perform better.

6.5 Conclusions

In this chapter the research area is further narrowed down identifying the specific a specific gap in knowledge to fill. The following conclusions have been drawn and will be used to construct the research methods for descriptive study 2 in the following chapter.

- Creative tools were identified as a useful method of validating research hypotheses, whilst also providing a vision of the implementation of the research findings.
- Creativity support tools have been categorised from several viewpoints within the literature reviewed (section 6.1).

- A simple descriptive representation can realise the distinction between creative Stimuli tools and other creative support tools available (section 6.1.4).
- Creative Stimuli tools can be distinctly categorised (Table 6-2) by the Relevance of the Stimuli retrieved and the Source of the stimulus relative to the industrial domain in which the task is set (section 6.2.1).
- A distinct gap in knowledge was identified regarding the potential of Stimuli retrieved from Sources Internal to the domain in which the task was set (section 6.2.2).
- Exemplar tools from each of the four categories of creative Stimuli tools are proposed as relative points of validation (section 6.2.3).
- An Information Management Creative Stimuli (IMCS) tool is proposed along with a repeatable process for simulation (section 6.3), satisfying Objective E.
- A research hypothesis is produced stating Type C and D tools will outperform tools A and B within the case company (section 6.4).

7 Descriptive study 2 – Stimuli testing

In chapter 6 a method was described to assess stimulus types C and D (Table 6-1) against stimulus types A and B used by other tools. In this chapter an industrial study is detailed to test these stimulus types along with the results produced. The chapter will consist of an introduction (section 7.1) introducing the various research questions answered by the study, followed by the research method undertaken (section 7.2). The ideas produced within brainstorming sessions (section 7.3), the effect of introducing Stimuli (section 7.4) and the relative performance of the stimulus types (section 7.5) are analysed and discussed.

7.1 Introduction

In order to produce creative ideas required for innovation, the preferred technique within industry is still traditional brainstorming (Osborn 1963) despite the growing body of research identifying its limitations (Isaksen and Gaulin 2005). During participation action research within the case company it was identified that the brainstorm session, a key component of the ideas stage of the innovation process could be both targeted for improvement whilst analysing the potential of prescribed creative Stimuli tools (see chapter 6).

The following additional background (section 7.1.1) is an extension of the review of related literature, reviewed in sections 5.4 and 5.5, and is directly relevant to the methods and results described in this chapter. The fundamental research questions which this descriptive study addresses are then identified. These are constructed in terms of the ideas produced throughout an uninterrupted brainstorm session (section 7.1.2), as a result of introducing Stimuli (section 7.1.3) and the relative performance of the various types of stimulus (section 7.1.4).

7.1.1 Background

Many studies have been made regarding creative idea generation, most based around research from cognitive psychology. Typically these have contributed with large

sample sizes and a rigorous scientific approach. However, many of these studies use only hypothetical problems, studying ideas from non-professional engineers (Massetti 1996; Benami and Jin 2002; Nijstad *et al.* 2002; Helquist *et al.* 2007; Perttula and Sipila 2007). Furthermore, few studies use the industrial evaluation during real projects to evaluate ideas generated, instead using experimental, hypothetical evaluation. As far as the author has been able to establish from the extensive review of literature, this study will be the first of its kind, using **real engineers** with **real design tasks** through **industrial processes**, objectively analysing ideas in terms of the **actual concepts and solutions** created from the ideas.

Previous studies regarding the effectiveness of creative Stimuli have limitations to validity, due to the 'artificial' nature of the experimental methods used. Benami (2002) views conceptual design as the process of creating functions, behaviours and structures, a view shared by the research. As an example (Gero and Kannengiesser 2003), consider the design of a Nokia mobile phone (Figure 7-1). Here it can be seen how the functions (F), behaviours (B) and structures (S) relate to each other through the viewpoint of a commercial product (see also section 2.2).

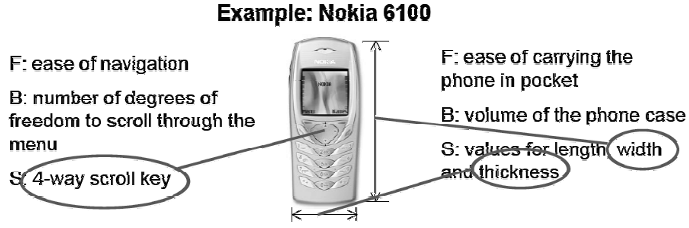


Figure 7-1 – FBS examples for the Nokia 6100 (Gero and Kannengiesser 2003)

In a previous study, Benami (2002) exhibits results showing that creative stimulus displayed as functions, behaviours, structures and as knowledge elements produced on average 3, 6, 5, and 2 ideas respectively. From this it was deduced that more ambiguous Stimuli tended to be less fixating, enabling designers to produce more ideas as a result. However, this study did not provide evidence to suggest that the use of Stimuli is more effective than generating ideas without. It also takes a hypothetical design task, posed in such a way that the ideas generated will be 'behavioural' ideas. Further effects of Stimuli and contextual cueing were described

by Liikkanen (2006), showing that there are a notably greater number of ideas generated in a particular category depending on the particular stimulus experienced.

Nijstad (2002) performed a similar experiment to asses how stimulating/suppressing ideas (proposed by other group members) are to an individual, though they only conducted the experiment using electronic representations of group ideas. In this study the design task was posed in such a way that the ideas generated were likely to be 'functional' ideas. This study concluded that the productivity of idea generation is increased in any of the four experimental conditions in which individuals were subjected to previous ideas in comparison to the control group.

7.1.2 Ideas produced during free thinking brainstorming

During the free thinking section of the brainstorm (see Figure 7-2), ideas are generated by group members with no prescribed stimulus. In section 7.3 these ideas will be analysed in terms of the following three detailed research questions (RQ's):

RQ 1 – *At what time and rate are ideas generated during each brainstorm session?*

Previous studies have shown declines in ideas produced per unit time (Helquist *et al.* 2007). During the author's time within the case company, it was realised that each brainstorm session often reached an 'idea saturation point', where members appeared exhausted of ideas. Often this point was recognised by the project manager at around 40 minutes where Stimuli were introduced to reinvigorate the group. The hypothesis would therefore be that the rate idea generation would steadily reduce hitting a saturation point at roughly 40 minutes.

RQ 2 – *At what time and rate are Appropriate ideas produced during each brainstorm session?*

Though it is often suggested that early ideas are not the best, with the most creative coming later, there has been very little academic work to support this. The author predicts that there will be an initial period producing several Appropriate ideas as the result of preconceived ideas during the briefing. After this initial period it is hypothesised that the number of Appropriate ideas per number of ideas will steadily decrease in frequency for the remainder of the session.

RQ 3 – *What percentage of chosen concepts contain ideas created during each brainstorm session?*

This is an un-researched area and thus is difficult to predict. For the brainstorming session to be a worthwhile part of the innovation process it would be expected that at least half the chosen concepts would contain ideas from the original brainstorm. Through multiple first hand experiences of the case company's innovation process, it can be predicted that this will be achieved.

7.1.3 Ideas produced under the influence of stimuli

Following the free thinking section of the brainstorm, ideas are generated by group members influenced by prescribed Stimuli (see Figure 7-2). In section 7.4 these ideas will be analysed in terms of the following three detailed research questions (RQ's):

RQ 4 – *How does the introduction of stimulus affect the rate of idea generation?*

Based on previous findings (Nijstad *et al.* 2002), it is expected that the quantity of ideas produced will be raised due to the introduction of the stimulus. However, it is quite feasible that 'off task conversation' or some form of digression may be stimulated as a result, thus lowering the Appropriateness rate of idea generation.

RQ 5 – *How does the introduction of stimuli affect the rate of Appropriate idea generation?*

Though this has not been covered by previous studies it can be predicted that the Stimuli will increase the number of Appropriate ideas produced, due to the increased quantity of ideas being produced. The diversity of ideas produced as a result of the particular stimulus may also lead to more Un-Obvious-Appropriate (see section 2.3.2) ideas.

RQ 6 – *How many ideas influenced by the stimulus exist within new concepts?*

This issue refers to the relative number of ideas that are influenced by stimuli and form part of a concept (a semi-detailed solution at the stage gate) not previously conceived during the free thinking brainstorm. The diversity of ideas expected to be produced as a result of the stimulus should provide several Original ideas leading to new concepts.

7.1.4 Comparison of stimulus types

In section 7.5 the different Stimuli tools are compared in terms of fluency and quality of the ideas produced. The Stimuli tools will be compared with reference to the following detailed research questions (RQ's):

RQ 7 – *How do the different stimuli tools perform in terms of rate of idea production?*

It is unknown how the different stimulus types will affect the rate of idea production. It was expected that the External Stimuli will probably produce more divergent thinking and thus a greater number of ideas, though not necessarily related to the stimulus or Appropriate to the problem.

RQ 8 – *How do the different stimuli tools perform in terms of idea Appropriateness?*

It has been hypothesised in section 6.4 that the Internal Stimuli tools will produce more Stimuli with on average higher Relevance to the problem and thus will produce more Appropriate ideas. However, these ideas must be of a good enough quality to be selected as Gate Ideas.

RQ 9 – *How do the different stimuli tools perform in terms of idea Originality?*

It is thought that the External Stimuli tools will produce marginally more Original ideas due to the more abstracted nature of the Stimuli.

RQ 10 – *How do the different stimuli tools perform in terms of idea Un-Obviousness?*

It is thought that due to the Un-Apparentness at relatively high levels of Relevance of Stimuli from Internal Sources, they would produce more Un-Obvious ideas.

7.2 Method

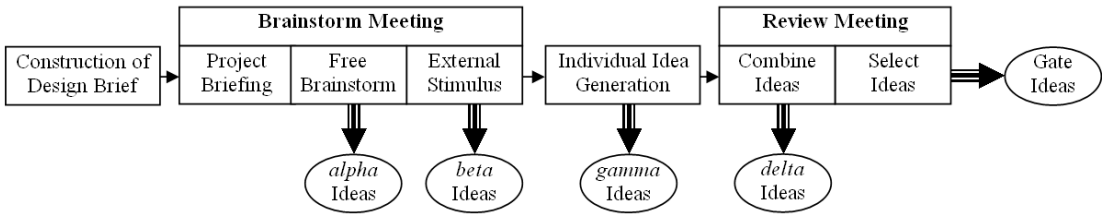
Unlike traditional research approaches, the method used was constructed to take advantage of a unique opportunity within an industrial innovation hub. Though, sample sizes were small and some variables were left uncontrolled, this gave the possibility to participate and capture *real* design activities with professional engineers. The following section will introduce the reader to; the ideas stage of the innovation process (section 5.1.5) analysed in each case (section 7.2.1); the details of the design projects and the designers (section 7.2.2); followed by the methods used to

capture the ideas (section 7.2.3) and evaluate them (section 7.2.4). The types of stimulus introduced are all described, in section 7.2.6.

The research method constructed for this study was built around the case company's practices. The company's standard innovation process was followed, as for all regular new projects. It was the decision of the author to concentrate the study in the ideas stage up to the first stage gate (Figure 7-2) where it is thought this research on stimulation for conceptual design will have most effect.

7.2.1 Ideas stage of innovation process

In each of the case projects under study, the following process was followed consisting of components, the brief, the brainstorm meeting, the individual idea generation, the review meeting and finishing at the stage gate. The outputs are ideas, categorised by the component or sub component in which they where produced.



alpha ideas: Idea generated by during the free thinking brainstorm session.

beta ideas: Idea generated after group is exposed to prepared stimuli.

gamma idea: Idea generated individually after the brainstorm session.

delta idea: Idea generated by combining ideas during the review meeting.

Gate Idea: An Appropriate idea embodied within the gate concepts put forward for presentation at the gate meeting.

Figure 7-2 – Case company innovation process (up to the first stage gate)

Construction of brief: Each design project studied began during the construction of the project brief. During this stage, the mission statement for the project is set, along with the various 'musts' and 'desirables' required for the design solution. The project manager is allocated and a team of approximately seven is assembled for a brainstorming session to generate solution ideas for the brief.

Brainstorm meeting: Within this session, roughly the first 30 minutes would consist of communicating the project brief to the team member's whist trying to frame the problem at hand. This is commonly followed by a free thinking brainstorm lasting roughly 70 minutes during which *alpha*-ideas will be generated. Of the chosen case projects numbers 1-5 (see Table 7-1) presented in this chapter, four had Stimuli prepared. The Stimuli were presented in turn after roughly 40 minutes to aid the session; the ideas produced during this period were termed *beta*-ideas.

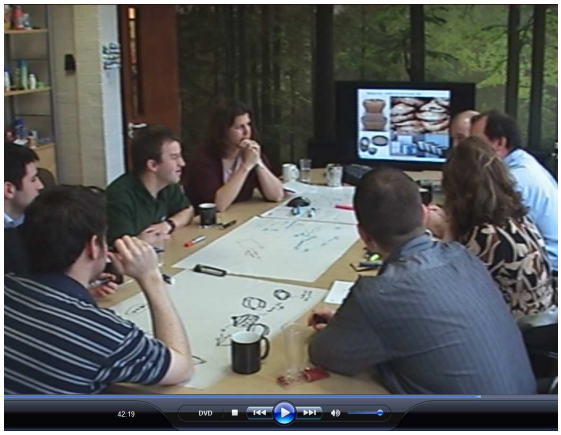


Figure 7-3 – Screen capture of typical brainstorm meeting

Individual idea generation: During this phase each team member is given roughly 1 week to produce 6 ideas (these ideas are to be in concept form, complete with function, behaviour and structure). These *gamma*-ideas can be constructed from ideas that they particularly like from the brainstorming session or as a result of a totally new idea generated. Each concept is named and drawn on an individual sheet.

Review meeting: During this review meeting team members exhibit each of their individual *gamma*-ideas and are encouraged to group idea by similarities and to make new and useful combinations of the ideas, noted as *delta*-ideas. After all ideas have been shared the groups of ideas are refined. At this stage several of the ideas are rejected due to them being inappropriate. The project manager will then draw up the selected ideas in the form of several gate concepts for the 1st stage gate report. The stage gate concepts resulting from the review meeting will inevitably be a mixture of the chosen *alpha*-, *beta*-, *gamma*- and *delta*-ideas.

7.2.2 Case project details

In total, the author attended over 15 brainstorms and review sessions. The projects listed in Table 7-1 and Table 7-2 were recorded, comprising of approximately 40 hours of footage. However, only projects in Table 7-1 were chosen for extensive analysis as they were more comparable than those listed in Table 7-2. During project Sweet (Table 7-2), a pilot study was conducted where the intervention using creative tools was made during the individual idea generation component. This approach was abandoned to concentrate on the group brainstorm session due data capture issues. Of the remaining 9 recorded projects below, 2 were archived preventing the evaluation of the ideas and 2 were deemed too unorthodox to compare. Each project is described in more detail using non-commercially sensitive language (Appendix B).

In the first four projects different Stimuli types were introduced, these will be further explained in section 7.2.6. As it was deemed the most vital from the task Major Area (section 4.2) the stage of the design process (DP) was constricted to the Ideas stage. Though the projects were raised from the various business types within Crown Packaging, most briefs were open enough to allow solutions from all business types. Details of the different business and project types are defined in section 5.1.4.

All analysed projects contained only Crown Packaging personnel with various job roles though the majority of brainstorm attendees were from the innovation department. The project managers were also the brainstorm facilitators and were deemed very influential. In all of the assessed projects experienced designers (Exp.) took the role of project manager rather than the trainee designers (Tra.).

Project number	Project name	Stimuli Type	Stage of DP	Bus. type	Proj. type	Proj. manager	No. of partic.
1	Polyrim	A	Ideas	Food	Carrot	Exp.	9
2	Blackbird	B	Ideas	Food	Customer	Exp.	8
3	Warhol	C	Ideas	Food	Customer	Exp.	9
4	Circus	D	Ideas	Beverage	Carrot	Exp.	9
5	Snus	None	Ideas	Special	Customer	Exp.	6

Table 7-1 – Details of chosen case projects

Project name	Stimuli Type	Stage of DP	Bus. type	Proj. type	Proj. man.	No. of partic.	Reasons for rejection from further analysis.
Dial	None	Ideas	Special	Carrot	Tra.	7	Inexperienced project management
Smash	None	Ideas	Food	Customer	Tra.	8	The project was archived preventing idea evaluation
Jumbo	Random word	Ideas	Food	Carrot	Tra.	7	The project was archived preventing idea evaluation
Beanstalk	None	Ideas	Food	Customer	Exp.	8	Unorthodox brainstorming procedure
Sweet	None	Ideas	Food	Customer	Exp.	13	Used in pilot study.

Table 7-2 – Details of partially analysed projects

7.2.3 Idea capture

As part of the agreement with the case company the session was video and audio captured with synchronised capture of both PowerPoint slides and 'pen and ink' illustrations. The analysis software used to synchronise and code the data was Quindi© (www.quindi.com) meeting companion which made the analysis and transcription more efficient. During this session the author participated as a designer, with no thought of evaluation of the session. Participation enabled the author to gain better understanding of the process and made retrospective analysis of the content of session easier.

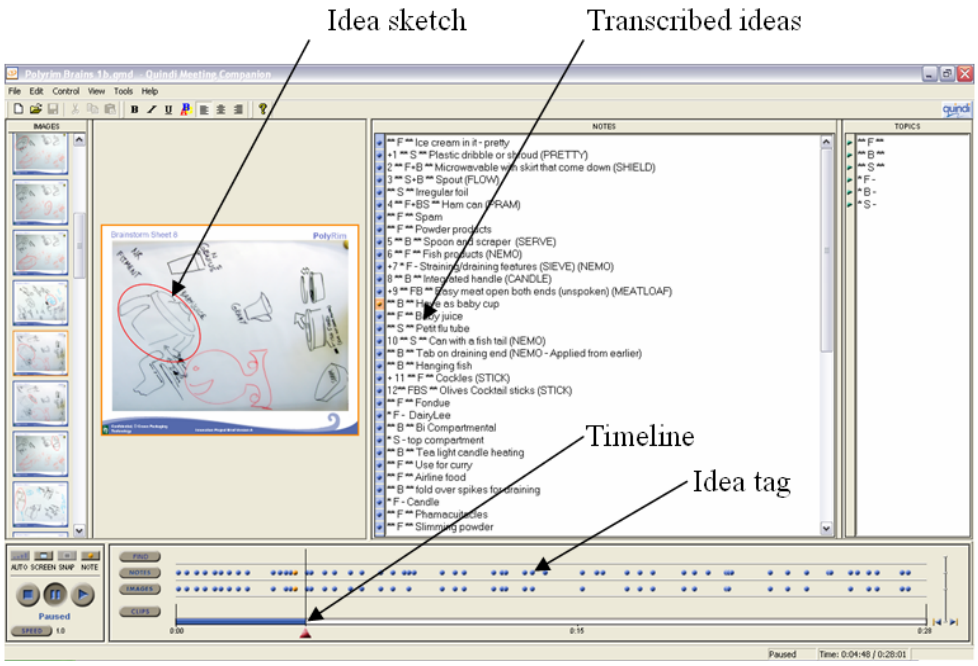


Figure 7-4 – Screen shot of capture software

When analysing the brainstorm sessions each statement, and in many instances, the attached illustration was tagged as either 'analysis', 'generation' or evaluation', see section 2.2. It was later decided that the generation statements were to be the focus and were broken down further in terms of, whether the statements refer to the function, behaviour or structure of a concept. These sometimes existed together, where group members may propose entire concepts. All ideas tagged were annotated chronologically along the meeting timeline.

To validate this notation of generation statements, an inter-observer reliability check was conducted. Three researchers were asked to mark up 10 minutes of video and audio footage each. Each was given the classification scheme and asked to place a note where an idea (a generation statement) had occurred along with a description of the idea. On comparison of the results with the author's notation, it was shown to be a good validation where the fellow researchers missed only 14% of the ideas, identifying the rest correctly. It is likely that this 14% can be put down to difficulties hearing each member of the group clearly. It is also thought that the author was better placed to make judgment on each statement/ideas due to having first hand experience of the brainstorm session and hours more practice using the mark-up scheme.

7.2.4 Idea evaluation and selection

Each brainstorm and the stimulus used is analysed along its timeline by the frequency of the ideas generated. In order to evaluate each idea for its creativity, it must be assessed for its Un-Obviousness, Appropriateness and Originality (Howard *et al.* 2006). However, due to the experimental procedure used for this study, drawing conclusions regarding Un-Obviousness is difficult as it is the tools and stimuli being compared rather than the individual ideas. Each term was measured as follows (the full argumentation for the definitions can be found in sections 2.3.2 and 4.5):

Un-Obviousness: This relates to how Obvious a solution association is to the problem. This is to be assessed as a *function of time*. The longer it takes the designer to produce an idea the more Un-Obvious it is deemed to be. This was thought to be the most objective way to asses this term.

Appropriateness: This relates to the validity and usefulness of the idea. As an objective measure for an idea's Appropriateness, it is analysed in terms of the concepts put forward at the gate review. If an idea forms part of a concept at the gate review in terms of its function, behaviour or structure, it is deemed Appropriate.

Originality: This relates to novelty or newness of the idea. As an objective measure for an idea's Originality it is analysed in terms of the concepts put forward at the gate review. If an idea is the first idea associated to a particular concept then it is deemed Original. If it is not the first idea associated to the concept it is seen as more of a developmental idea.

Both Appropriateness and Originality rely on a concept idea breakdown. An example of this concept - idea breakdown, based on project number 4 can be seen in Figure 7-5. In the example, the circular figures represent ideas that have been selected as Appropriate and used at the ideas gate. At this gate the ideas are arranged into 'semi-detailed solutions' termed concepts or gate concepts. It can be seen from Figure 7-5 that several ideas refer to the same concept, the first idea assigned to a concept is deemed as Original.

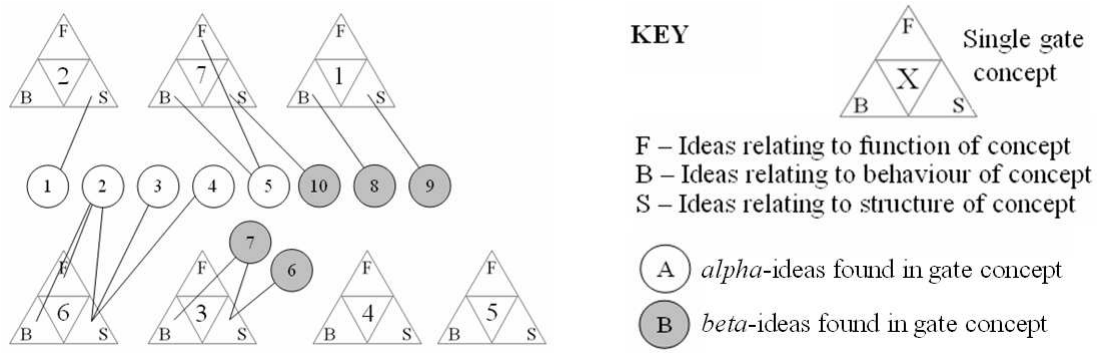


Figure 7-5 – Concept – Idea breakdown

7.2.5 Notations validation

To validate this notation one of three researchers was given both the Gate Ideas and the concepts for one project. The researcher was given the definitions for function, behaviour and structure and was then asked to mark the connections between the *beta*-Gate Ideas and the functions, behaviours and structures of the concepts (as shown in Figure 7-5). The researcher was also given an example of this mark-up

from another project to work with. After comparison it was shown that there was good likeness where the researchers attributed 80% of the *beta*-Gate Ideas to the same concepts as the author's mark-up. In follow-up discussion it was identified that the unmatched 20% was due to a lack of the researcher's knowledge of the design task and a lack of information made available. Also, the researcher annotated each idea in terms of function, behaviour and structure of which 92% of the author's notation was correctly identified. Interestingly, 20% of the research notation was additional to those provided by the author.

7.2.6 Types of stimulus

Brainstorm groups in projects 1-4 were subjected to Stimuli during the brainstorm session, of which the following four different types of Stimuli were used drawn from a 2x2 matrix (see Table 6-2):

Type A tool: Prompting External generated Stimuli in a Random fashion
Type B tool: Prompting External generated Stimuli in a Guided fashion
Type C tool: Prompting Internally generated Stimuli in a Random fashion
Type D tool: Prompting Internally generated Stimuli in a Guided fashion

Each group was exposed to the individual stimulus in the form of a presentation slide, which contained pictorial information with some supporting text. Each slide was constructed to display roughly similar amounts of information. Table 7-3 shows examples of the slides proposed by the different Stimuli tools along with the process by which they were generated. Project 5 does not feature within Table 7-3 as this was a control group in which no Stimuli was presented.

In order to disrupt the brainstorm session as little as possible it was left to the group to decide when they would like to introduce the first stimulus which were loaded onto the end of the project brief document. The Stimuli were left on the screen until the group had exhausted its use and were ready to move onto the next. The Stimuli were used to the extent that suited the brainstorm group, however, in all instances there were continuously used until the end of the brainstorm session.

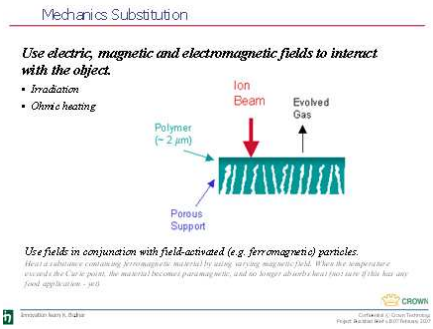
Stimulus Type	Example Stimulus
Project 1 The group is provided with stimulus from Type A creative Stimuli tool, External to the industrial domain Randomly retrieved from an Internet image repository.	
Project 2 Guided Stimuli External to the domain were provided by a Type B creative Stimuli tool in the form of TRIZ inventive principles retrieved from the contradiction matrix (Altshuller 1999). The contradiction was identified by independent researchers.	
Project 3 Random Stimuli Internal to the domain prompted by a Type C creative Stimuli tool in the form of concepts generated from previous projects. These were searched for and chosen at random by the author.	
Project 4 Guided Stimuli Internal to the domain were retrieved using a Type D creative Stimuli tool. For this project the Information Management Creative Stimuli (IMCS) tool (described in detail in section 6.3) was used.	

Table 7-3 – Stimuli types used in descriptive study 2

7.3 Ideas production during free thinking brainstorming

This section reports the rate of *alpha*-idea (see Figure 7-2) generation (section 7.3.1), the Appropriateness the *alpha*-ideas (section 7.3.2) and an assessment of the how the *alpha*-ideas relate to the concepts proposed at the gate meeting (section 7.3.3), addressing Objective G.

7.3.1 Rate of idea generation

Figure 7-6 displays the sequence of ideas created for each project during the group brainstorm session addressing RQ 1. All ideas correspond to statements and illustrations associated with idea generation (see section 7.2.3). Statements tagged as analysis or evaluation were omitted. The numbers at end points of each project line represents the total number of ideas to that point. The number in **red** represents the rate of idea generation (ideas/minute) up until that point.

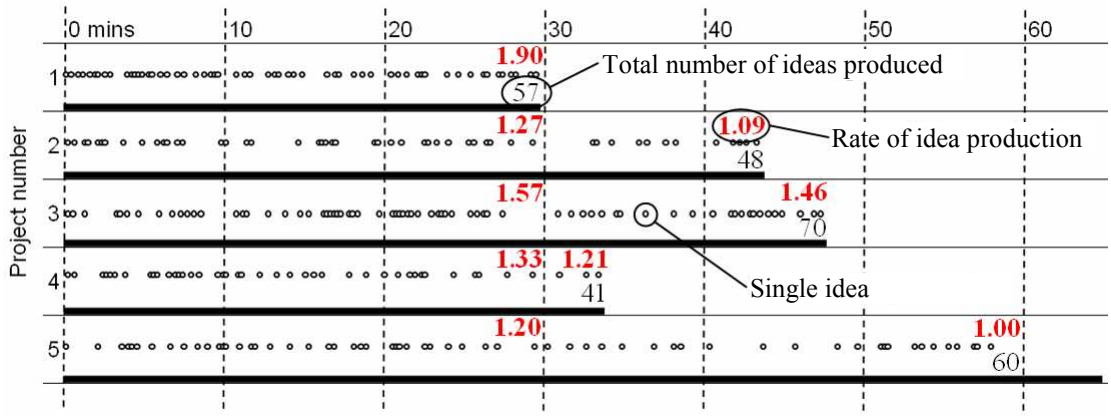


Figure 7-6 – *alpha*-Ideas produced during brainstorms

The plots (Figure 7-6) display typical characteristics of brainstorming, with several idea clusters (Nijstad *et al.* 2002) showing how new ideas spark developing ideas, for example providing corresponding behaviours and structure to fulfil the new functions proposed. It is quite evident from Figure 7-6 that the rate of idea generation is relatively constant throughout the brainstorm sessions, contrary to the hypothesis and previous findings (Helquist *et al.* 2007). However, each brainstorm did exhibit a slight reduction in idea generation rate after about 30minutes. The brainstorms also show little sign of exhaustion, with the exception of project 5 where no ideas were generated in the last 8 minutes of the session. Project number 1 produced noticeably more ideas then the other projects.

7.3.2 Gate ideas produced

Figure 7-7 shows the ideas displayed in Figure 7-6 which turned out to be most Appropriate. These ideas became Gate Ideas forming a part of a concept documented at the stage gate. The numbers above the ideas are the numbers given to each Appropriate *alpha*-Gate Idea.

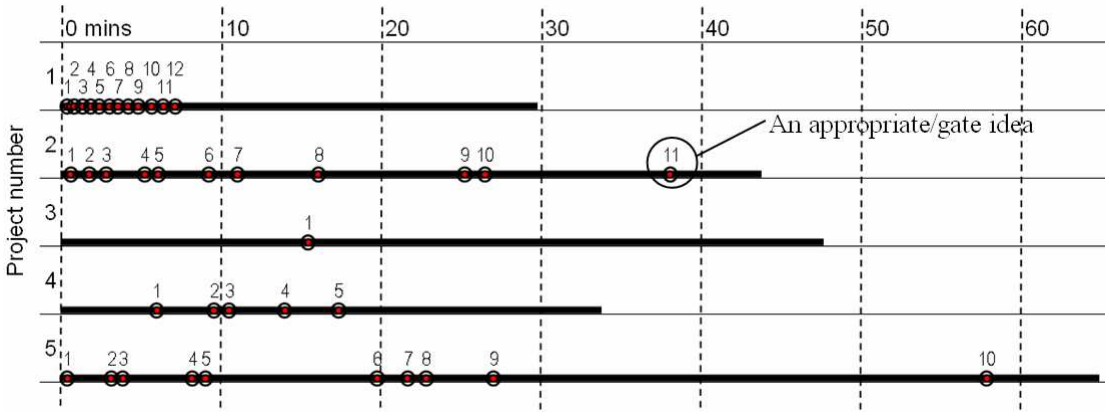


Figure 7-7 – *alpha*-Gate ideas produced during brainstorms

The above (Figure 7-7), sheds new light on the findings displayed Figure 7-6. As suggested under RQ 2, there is a general influx of Appropriate ideas during the early stages. However, where the ideas plot (Figure 7-6) suggests idea generation performance stays relatively constant, it can be seen that producing Appropriate ideas becomes more and more difficult with time. On average the first 20minutes contains over 80% of session ideas (*alpha*-ideas) found within the Gate Ideas and thus the gate concepts (see Figure 7-2 and Figure 7-5).

7.3.3 Gate concept breakdown

Of the ideas that were selected as Gate Ideas shown in Figure 7-8, only the ideas highlighted in **Red** text are Original, the rest are developmental. As this is the first idea generation component (*alpha*-ideas) of the ideas stage it is logical that the *alpha*-Gate Ideas are predominantly Original. The Gate Ideas produced in later components (i.e. *gamma*-Ideas and *delta*-Ideas) will contain a higher percentage of developmental ideas.

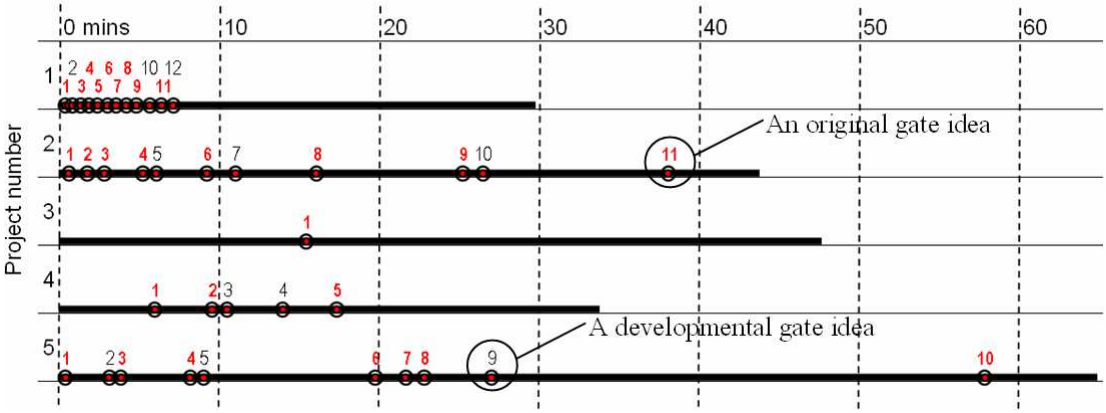


Figure 7-8 – *alpha*-Original gate ideas produced during brainstorms

Figure 7-9 shows the percentage of concepts containing the *alpha*-ideas from each brainstorming session addressing RQ 3. For example, project 1 had 13 concepts at the stage gate, 10 of which contained ideas generated during the brainstorm. An average of 64% of stage gate concepts contained ideas generated within the brainstorming session, thus suggesting that it is a worthwhile phase of the innovation process. This is regarded by the authors as an important statistic suggesting that only 36% of stage gate concepts are attributed to work outside the 'free thinking' brainstorm.

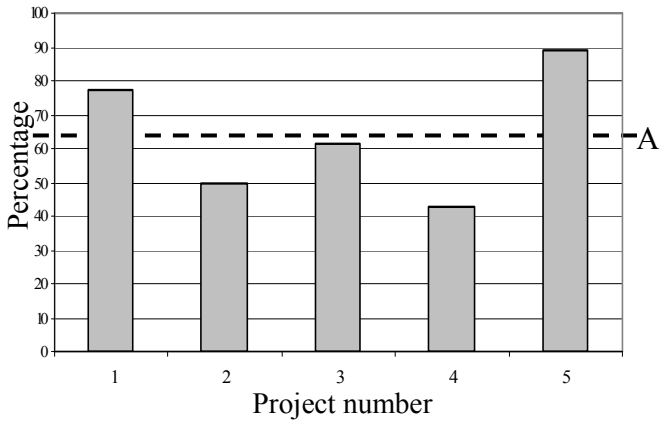


Figure 7-9 – Concepts containing *alpha*-ideas for each brainstorm

7.4 Effects of introducing stimuli

This section addresses Objective H displaying results regarding the rate of *beta*-idea generation (section 7.4.1), the Appropriateness of the *beta*-ideas (section 7.4.2) and an assessment of the how the *beta*-ideas relates to the concepts proposed at the gate meeting (section 7.4.3) and thus the Originality of the ideas..

7.4.1 Rate of idea generation

Figure 7-10 shows the brainstorming timelines of the five projects. The first black line of each project represents the free thinking brainstorm session which follows the project briefing. Each section of **orange** and **blue** line represents the introduction of new stimulus to help inspire new ideas, with the number above representing the number of ideas produced under that particular stimulus. The final shorter dark line represents the closing discussion. The numbers at points of each project line represents the total number of ideas to that point. The number in **red** represents the rate of idea generation (ideas/minute) up until that point. The figure in **red** at the end of the Stimuli section represents the rate of idea production of the *beta*-ideas only.

It is clear, both from first hand experience and the plot in Figure 7-10 that the Stimuli helped to maintain the rate of idea generation. In all instances the rate of *beta*-idea production is higher than projected without the use of Stimuli. In projects 1, 2 and 4 the rate of *beta*-idea production was actually higher than the rate of *alpha*-idea production. Project 3 was slightly lower, however if the first stimulus was removed the rate of *beta*-ideas would have been the same as the 30minutes rate *alpha*-ideas.

It is thought that the Stimuli helps to maintained the rate of idea generation at this late stage of the brainstorm session from the added interest and motivation experienced by the group from using the Stimuli. However, there were more direct and apparent effects of the stimulus where elements of the Stimuli actually inspired ideas; backed up by feedback from the participants *"The segmentation one certainly sparked a few ideas"*. The stimulus also provided a starting point for participants to begin discussion and lateral thinking: *"secondary conversation that was quite productive actually"*.

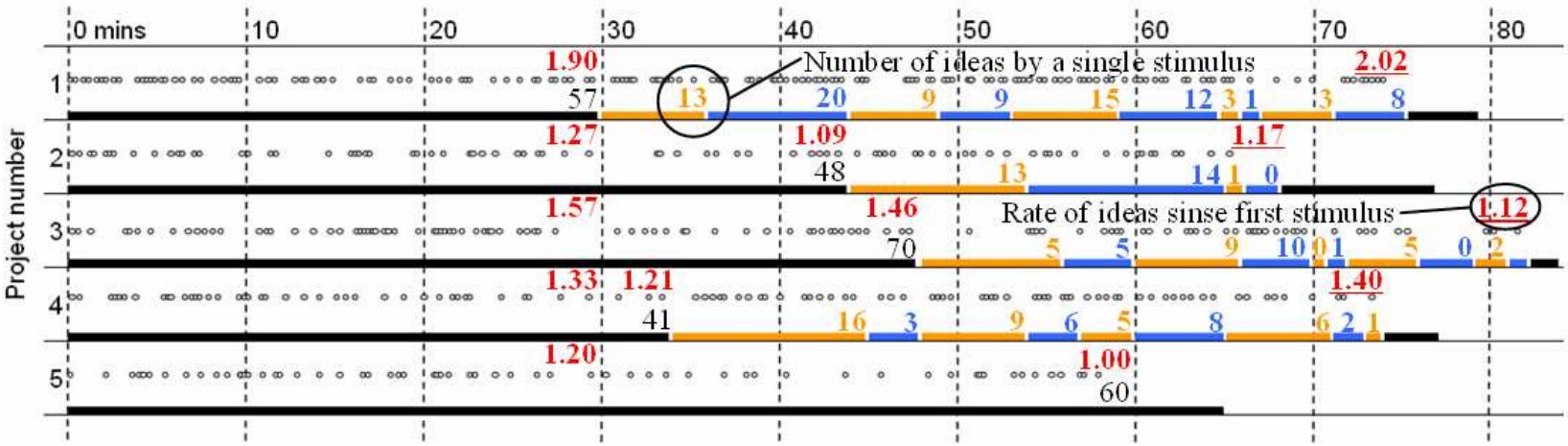


Figure 7-10 – Project brainstorm session idea timeline

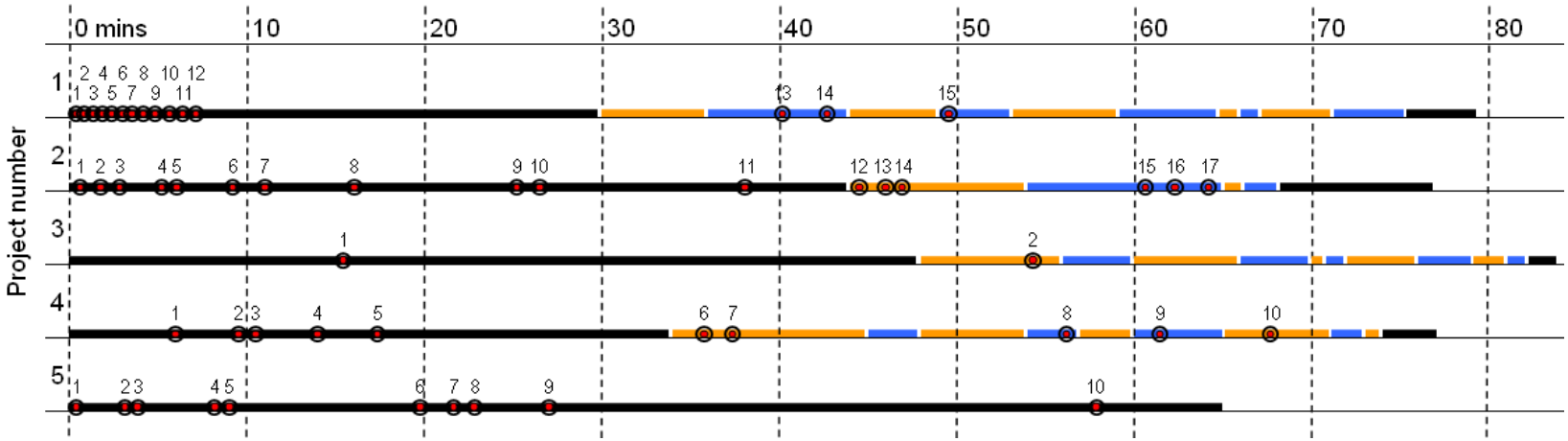


Figure 7-11 – Project brainstorm session idea gate timeline

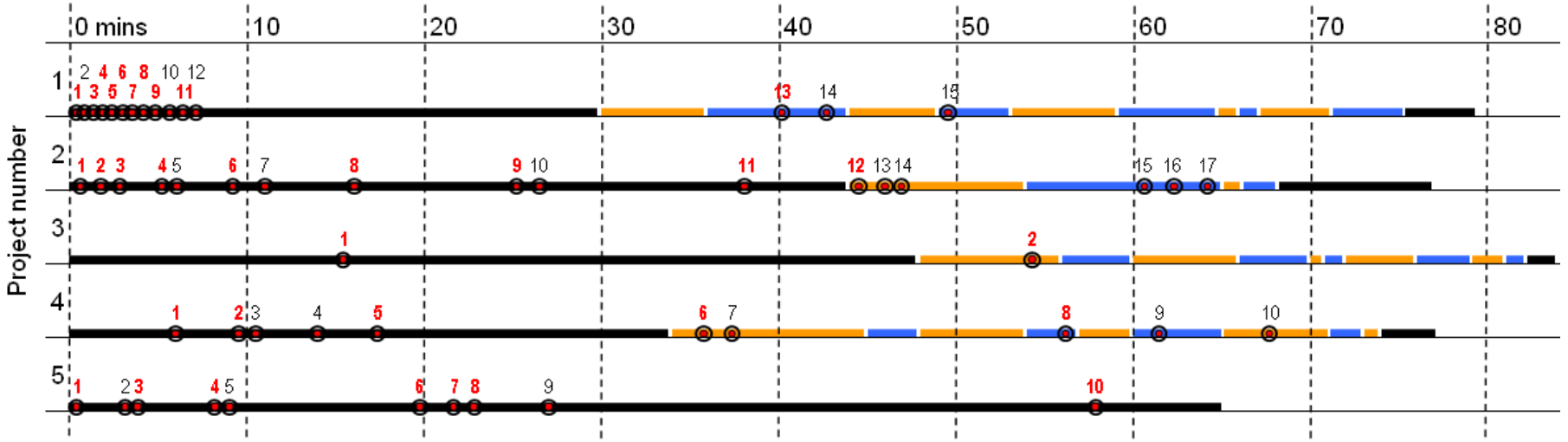


Figure 7-12 – *alpha* & *beta*-Original gate ideas produced during brainstorms

7.4.2 Gate ideas produced

Figure 7-11 shows which of the ideas displayed in Figure 7-10 turned out to be most Appropriate, becoming a constitute of a concept at the stage gate. Each of these numbered Gate Ideas are represented by the numbered targets along the time lines in Figure 7-11.

It is clear from the above that the Stimuli in general had a positive effect on the ideas being generated. A higher proportion of Gate Ideas were produced under the influence of Stimuli than could be expected at the particular late stage of the brainstorm session especially when compared against the control group, project 5. This would suggest the use of stimulus in general helps to produce more Un-Obvious-Appropriate ideas as predicted in the hypothesis for research question 5. There are several examples in the data where the stimulus directly influenced the nature of the Gate Ideas.

7.4.3 Gate concept breakdown

Of the ideas that were selected as Gate Ideas shown in Figure 7-12, only the ideas highlighted in **Red** text are Original, the rest are developmental. As more Gate Ideas are produced, the chances of generating an Original idea are decreased. The quantity and percentage of *beta*-Gate Ideas is expected to be less than that of *alpha*-Gate Ideas.

Figure 7-13 shows how the *beta*-Gate Ideas spread over the gate concepts for the four projects provided with stimulus. The total number of Gate Ideas produced from the *beta*-ideas is represented by the white columns. This consists of Original ideas and developmental ideas. The total number of different concepts containing *beta*-ideas is represented by the hatched columns, giving some idea as to how diverse the ideas are. Arguably the most valuable measure is that of the Original *beta*-ideas, represented by the grey column. An Original *beta*-idea can be classed as heterogeneous and is the first idea to be associated with a new gate concept.

From Figure 7-13 it can be seen that on average only 1 Original idea is produced as a result of a *beta*-idea (inspired by prescribed Stimuli). This did not really support the hypothesis that the diversity of the stimulus would lead to more Original *beta*-Gate Ideas, instead suggesting that the stimulus aids in the development of concepts more 'how to' then 'what else'. It appeared that the groups given the Guided stimulus (projects 3 and 4) performed better producing, on average, more *beta*-Gate Ideas; though most of the ideas proved to be developmental ideas rather than Original or heterogeneous ideas.

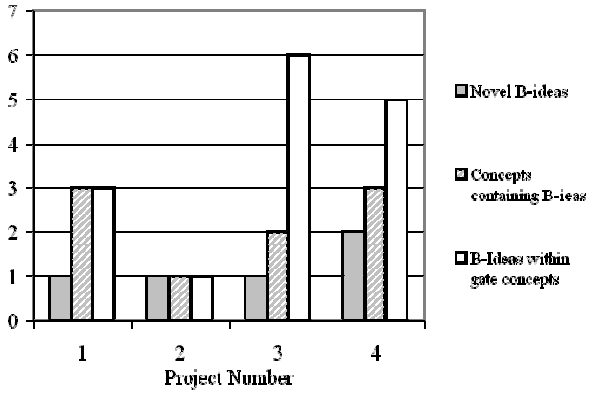


Figure 7-13 – *beta*-idea to concept breakdown

7.5 Comparison of stimuli types

This section compares results from the four different Stimuli tools addressing Objective I. Each is analysed in terms of the rate of idea generation (section 7.5.1), the Un-Obviousness (section 7.5.4), Appropriateness (section 7.5.2) and Originality (section 7.5.3) of the ideas produced, along with the qualitative analysis throughout.

7.5.1 Rate of idea generation

Information was taken from Figure 7-10 and put into a format for comparison in Table 7-4, addressing RQ 7.

	Tool A *Ext. Rand.* (project 1)	Tool B *Ext. Guid.* (project 2)	Tool C *Int. Rand.* (project 3)	Tool D *Int. Guid.* (project 4)
Most ideas from single stimulus	20	14	10	16
Highest idea rate of stimulus (Ideas/min)	2.5	1.3	2.5	2.0
Longest time of stimulus (min)	8	11	8	11
Total time using stimuli (min)	46	24	34	40
Number of stimuli producing ≤3 ideas	5	2	5	3
Rate of *beta*-idea generation (Ideas/min)	2.02	1.17	1.12	1.40
Rate of generation of *beta*-ideas/*alpha*-ideas	1.06	1.07	0.77	1.16

Table 7-4 – Comparison of rates of idea generation of stimuli tools

Tool A produced the most ideas from a single stimulus, at 20 ideas. However, this figure is not very representative of performances as the particular task and designers in project 1 were more conducive to idea generation, producing more ideas per unit time than in the other projects. The Random Retrieval Tools, A and C produced the best performing stimulus in terms of rate of idea generation at 2.5 ideas per second. However, as expected, this was contrasted by the higher number of Stimuli which produced no ideas.

The most interesting and telling statistic details the rate of *beta*-idea generation to be higher than the rate of *alpha*-idea production in project 1, 2 and 4 with only tool C producing less ideas. The highest (relatively) performing was the Type D Stimuli tool increasing the rate of idea production by 16%. It also was observed that Type C and D tools produced a higher quantity of ideas, which were directly associated with the Stimuli.

7.5.2 Appropriateness of ideas

Table 7-5 displays information taken from Figure 7-11 giving details of how each Stimuli tool has performed in terms of Appropriate ideas (Gate Ideas) produced, addressing RQ 8.

	Tool A *Ext. Rand.* (project 1)	Tool B *Ext. Guid.* (project 2)	Tool C *Int. Rand.* (project 3)	Tool D *Int. Guid.* (project 4)
Most gate ideas from stimulus	2	3	1	2
Number of *beta*-gate ideas	3	6	1	5
Number of directly inspired ideas	1	3	0	1
Number of abstractly inspired ideas	0	3	1	3
Number of *beta*-gate ideas/total gate ideas	0.2	0.35	0.5	0.5
Number of stimuli producing a gate idea	2	2	1	4

Table 7-5 – Comparison of Appropriate ideas produced of stimuli tools

Type B Stimuli tool proposed 2 Stimuli each with 3, *beta*-ideas, more than any other tool. Both Guided Stimuli tools produced more ideas than the Random Stimuli tools. However, both Internal Stimuli tools produced a higher quantity of *beta*-Gate Ideas relative to the total number of Gate Ideas, providing compelling evidence for the potential behind Internal generated Stimuli. From the protocol analysis it was shown that the Guided tools (B and D) produced more ideas both directly and abstractly inspired by the Stimuli. Also, more of the Stimuli proposed from the Type D tool produced *beta*-Gate Ideas.

7.5.3 Originality of ideas

Figure 7-12 shows the Original ideas inspired by the different Stimuli proposed, addressing RQ 9. Stimuli tool Type D produced the most Original ideas. Both directed tools produced a higher quantity of Original ideas relative to the Appropriate ideas. This was the opposite of what was expected. One reason for this may have been in the definition of Originality being relative to a new concept rather than a novel entity within the concept.

7.5.4 Un-Obviousness of ideas

As previously stated, Un-Obviousness is quite controlled over the course of this study and is more suited for the comparison of individual ideas; thus RQ 10 is hard to answer. All *beta*-ideas produced are relatively Un-Obvious due to the delay before the stimulus is prescribed. In terms of what is deemed a creative idea, idea 10 in project 5 is the most Un-Obvious as it is the latest idea that is both Original and Appropriate.

7.6 Discussion

The following section will discuss the results and their implications relative to chapter 4 and shed light upon the research questions posed in the introduction. The results of this section provide strong evidence to support the hypotheses (section 6.4), and adds further insight into the previous related work (Benami and Jin 2002; Helquist *et al.* 2007). The discussion will first address the findings and observations from the 'free thinking' section of the brainstorm (section 7.6.1) and the *alpha*-ideas produced. In section 7.6.2 the *beta*-ideas along with the stimulus by which it was inspired is analysed. The section ends with the analysis of the different Stimuli tools (section 7.6.3).

7.6.1 Analysis of the free thinking brainstorm

Here the production of *alpha*-ideas is discussed, addressing Objective G. To consider RQ 1, the rate of idea production appeared to be constant throughout each session until roughly 30minutes then decreased slowly and steadily (see Figure 7-6). In accordance with many studies, under many forms of analysis, it could therefore be argued that the creative performance was roughly constant throughout the session. It was for this reason that RQ 2 has to be addressed regarding the Appropriateness of the ideas.

By following an industrial innovation process for real projects, the evaluation of how 'Appropriate' an idea was assessed in an objective manner. The robustness of this method gave clear and apparent insight into where Appropriate ideas are produced during a brainstorm. The results show that in all cases, over half the Appropriate *alpha*-ideas of the session are produced within the first 10 minutes (Figure 7-7). In the light of this, one conclusion would be that more time should be spent towards the end of brainstorming session on linear development of the ideas already produced.

To address RQ 3, Figure 7-7, Figure 7-8 and Figure 7-9 provide a revealing insight into how the ideas produced within the brainstorm session (*alpha*-ideas) influence the concepts at the stage gate. Backed up by observations, the results suggest that the majority of the ideas behind each concept at the first stage gate are provided by the

20th minute. This observation would not have been possible in a traditional experimental study, where there is no developed solution or concept by which to evaluate such ideas. This study therefore demonstrates a method by which ideas can be evaluated, using the actual success and impact on the future (stage gate) concepts proposed, rather than the hypothetical situations, commonly found in the literature.

7.6.2 Analysis of the influence of stimuli

It was important to establish whether the introduction and use of Stimuli tools had a positive affect in general, thus addressing Objective H. It would appear that the Stimuli prescribed to the brainstorming groups was well received, substantiated by the following quotes captured during the cool-down period of each brainstorm: *"If we'd have gone through those at the beginning we would have probably got these ideas quicker"*, *"Certainly if you could show in advanced it would have been quite useful"*, *"They were all quite good I thought", "The stimulus at the end was very good", "Very useful actually"*. It was quite evident at the time and through the video analysis that the Stimuli aided the group in terms of motivation and was introduced at certain points in the session where a lull in motivation was being experienced. It can be seen from the timelines (Figure 7-10) that the brainstorms with prescribed Stimuli lasted longer. Furthermore, the rate of idea production remained higher even at the later stages of the sessions when using the prescribed Stimuli.

From the analysis of Figure 7-7 it was suggested that the rate of Appropriate or Gate Idea generation reduces dramatically with time throughout the brainstorm session. It can be seen from Figure 7-10 that the introduction of prescribed stimulus helped to counteract this in all cases. The hypothesis from research RQ 5 was therefore supported. However, there is evidence to suggest from the video analysis and from the idea plots that this increased number of Appropriate ideas in the latter stages is not just due to an increase in the number of ideas. The Stimuli were useful for finding Un-Obvious ideas that were more Appropriate to the task than could have been expected without the stimulus.

The Originality of the ideas produced (RQ 6) was not significantly increased as expected, with more homogeneous Appropriate ideas being produced than ideas that

helped generate new concepts. This could have been due to the group trying to incorporate the principles taken from the stimulus into the existing ideas, or simply just a natural characteristic of these latter stages of the brainstorming sessions.

7.6.3 Performance analysis of the different stimuli tools

The actual performance of the tools is slightly different from the performance of the Stimuli in which they prescribe. In terms of usability, the Random tools are extremely easy to implement and should be relatively quick to prepare and use. The Information Management Creative Stimuli (IMCS) tool would take time to implement but once implemented could be used very quickly. The TRIZ contradiction matrix tool requires setting up for each problem; however this process does provide other benefits to the understanding of the problem.

In order to fulfil Objective I, the performance of the different Stimuli proposed by the tools must be discussed in terms of the quantitative and qualitative observations throughout descriptive study 2. From the protocol analysis it was realised that the Stimuli was as useful for removing solution blocks (similar to suppresative incubation in section 3.2.1) as it was for promoting new ideas (similar to stimulative incubation in section 3.2.1). In many instances the Stimuli did not work by directly inspiring new ideas but by diverting designers onto a new train of thought, enabling fresh and new ideas. In terms of directly prompting ideas, the Guided Stimuli tools worked better. The Random External Stimuli appeared particularly good at removing metal blocks, as the all members could easily relate to the Stimuli proposed.

It is believed that the Type D Stimuli tools out-performed the other tools in terms of the rate of ideas produced due to the ability of the Stimuli to stimulate and remove blocks. This was backed up by the quantitative results, the opinions of the brainstorming group and the dialogue assessed by protocol analysis. It is thought important that the stimulus carries meaning to the designer, to either stimulate new ideas or remove suppression. When using the Type B Stimuli tool the meaning or understanding behind the stimulus was not always so easy to decipher; in comparison to the more familiar Stimuli proposed by other tools. This is perhaps the most important criticism of the TRIZ inventive principles – without a thorough

understanding of the principle, which may require a domain expert; the stimulus has little value as 50% of the Stimuli proposed produce less than 3 ideas.

The overall quality (Originality, Appropriateness and Un-Obviousness) of the ideas produced show that the Guided Stimuli tools, Type B and D were most effective. They help to stimulate more Appropriate ideas at later stages of the brainstorm than the other tools. In terms of the affect of the variables of Relevance and Un-Apparentness it would appear that these favour neither the Type B or D tools but suggest that Type A and C tools have lower levels of Relevance.

8 Conclusions

This thesis has made theoretical and practical contributions to the field of engineering design. The cross disciplinary research conducted has brought findings from the domain of cognitive psychology and the experiments conducted have helped to provide understanding of the effects of creative Stimuli when introduced into an industrial setting.

The following chapter will give an overview of the research undertaken throughout this thesis (section 8.1). In section 8.2 the major contributions made are described in terms of the research aim, questions and objectives. The important recommendations to the case company are then described (section 8.3) before the recommendations for future work and the important limitation of this work are detailed in section 8.4.

8.1 Overview

Chapter 1 introduced the social and industrial importance of the area of study along with the research methodology chosen to conduct the research. In chapter 2 and 3 a complete theory was constructed showing how information can be used as creative stimuli, distinguishing a creative idea from a routine idea and affecting the eventual products designed.

In chapter 4 the criteria were identified and a Framework was proposed consisting of 3 levels. On the highest level were the 3 Major Areas of information, task and designer, which affect how stimulating a 'chunk' of information is to creative idea generation. These were then split into 7 characteristics and broken down to the variables associated to each characteristic. Central to the model was the 'task and designer dependent information characteristic'. This had two variables, Relevance and Un-Apparentness, that would be the focus of the industrial based study.

In chapter 5 the first descriptive study was carried out to examine how information was used within the case company and to identify the opportunities for sourcing

Stimuli. Profiles were created corresponding to the Major Areas identified in the criteria stage. The purpose was to identify what could practically be controlled in order to best nullify the effects of the other influencing variables. As a result the method for descriptive study 2 was constructed to only work within the ideas stage, and to avoid the use of metal closure and generic projects.

In chapter 6 a review of creativity tools was undertaken. A matrix was created of creative Stimuli tools, identifying Internally Sourced (to the domain or company) Stimuli to be a gap in knowledge. The prescriptive study then focused on taking advantage of the findings from the descriptive study and proposes a creative Stimuli tool based on Stimuli generated from the company shared file space. This tool would be tested against other established tools in order to test the Stimuli.

Descriptive study 2 (chapter 7) focused on the brainstorm sessions. All ideas were captured and recorded and the analysed. It was shown that the brainstorms followed an expected pattern with the rate of ideas steadily decreasing after 30minutes. Unexpectedly, it was shown that on average, over 80% of the Appropriate ideas were produced within the first 20minutes. It was also shown that on all accounts, both through projection and in comparison to the control group that introducing Stimuli has a positive effect; this is concurred by the qualitative findings. The support tool proposed (the IMCS tool) had positive results, quantitative evidence would suggest it performed as well as the TRIZ contradiction matrix (Type B tool) and qualitative evidence suggests it outperformed the Type B tool.

8.2 Contributions

The main aim of the research was to *"gain greater understanding of information as an input into the engineering design process in the form of creative stimuli"*. This aim was achieved through an extensive review of literature leading to several interlinking models produced from the theoretical work. Figure 8-1 shows how the

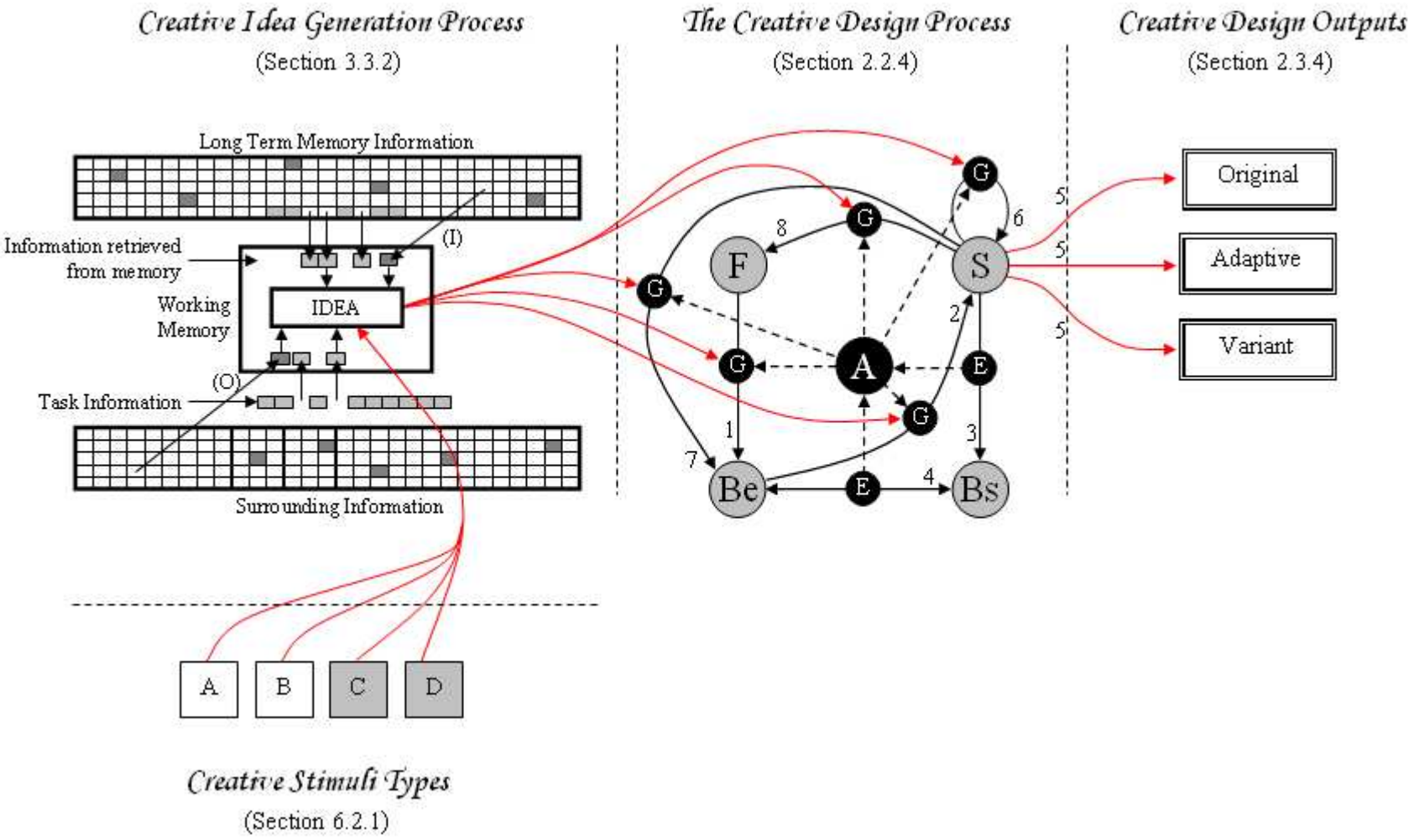


Figure 8-1 – Schematic representation of the theory of the effect of creative stimuli on engineering design

models proposed in chapters 2 and 3 link together, showing how the 4 types of Stimuli (proposed in chapter 6) can be used to produce type 'O' creative ideas, which in turn affect the creative design process influencing the creative design types produced.

Given the above theory summarised in Figure 8-1 the two research questions were addressed:

1. Is it possible to manage information within a company to be used as stimuli to aid creative idea generation?

In descriptive study 1, conducted within an industrial setting (chapter 5), the information use in the case company, Crown Packaging was analysed. As a result of this study, an approach was designed around the commonly used information storage repositories to *store*, *search* and *retrieve* information as Stimuli (section 6.3), to support creative idea generation. The approach was termed the Information Management Creative Stimuli (IMCS) tool and was shown to be manually repeatable providing scope for an electronic, automated version. The approach relies upon the consistent and effective management of information, a vision that underpins the Design Information and Knowledge (DIaK) research theme at the University of Bath.

2. How effective will Internally generated stimuli be in comparison with the other current approaches identified from with the literature?

In chapter 6 it was hypothesised that creative support tools retrieving Stimuli from Internal Sources would out perform those retrieving from External Sources. This hypothesis was formed from qualitative observations made, that information Internal to the industrial domain is preferred by designers as inspiration, particularly during brainstorm sessions. This is thought to be due to the generally higher levels of Relevance of the creative Stimuli, enabling those types to stimulate more ideas per stimulus. During descriptive study 2 (chapter 7), quantitative and qualitative evidence was gained to support this hypothesis.

However, the increase in Relevance is at a trade off with the decrease in Un-Apparentness of Stimuli. It is thought that the Stimuli are needed to be Un-Apparent

enough to produce Un-Obvious ideas needed at the late stage of the brainstorm in which the Stimuli was introduced. It was though that this factor enabled Stimuli from External Sources to inspire as many Gate Ideas as those inspired from Internal Sources.

In addition to the above research aim and questions, 9 more specific research objectives were laid out (section 1.3.3), all of which were addressed throughout this thesis, though not all were definitively satisfied (see Table 8-1).

Objective	Fulfilment
Objective A	This was fulfilled in section 1.4 by creating a novel and industrially based research methodology. The overall methodology was based on that proposed in previous literature (Blessing and Chakrabarti 1999), but also integrated a modern research approaches such as protocol analysis and participation action research from an insider perspective (Bjork and Ottosson 2007).
Objective B	This was fulfilled in section 2.4, proposing a theoretical model showing how the creative output affects an integrated creative design process influencing the creative design outputs produced (see Figure 8-1).
Objective C	This was fulfilled in section 3.3 by describing a cognitive mechanism that distinguishes a creative idea from a routine idea by the different categories of information used as inputs to the process. It is proposed that type 'O' generation uses Outer or surrounding information to inspire creative ideas.
Objective D	This was satisfied by proposing a framework, theoretically describing: • The 3 Major Areas (section 4.2) of Information, Task and Designer. It is believed that the task Major Area provides more influence over the effectiveness of Stimuli than previous research give credit.

- The 2 dominant and testable, influential variables of Relevance and Un-Apparentness of information were identified (section 4.3). These variables are positioned central to the 3 Major Areas.
- The 4 success criteria to measure the effectiveness of Stimuli. These included Originality, Appropriateness and Un-Obviousness of ideas, and the rate at which they are produced.

Objective E This was fulfilled by defining a distinct knowledge gap (section 6.2) in the use of information generated Internally to the domain as creative Stimuli. A creative support tool was also developed (section 6.3) to test Internal Stimuli against current tools within industry.

Objective F This was fulfilled during chapter 5 where an information use profile was conducted for the case company's innovation department, identifying opportunities for potential Stimuli. It was identified that the majority of information use sources were electronically on the public or shared hard drives, of which over 50% of information uses were in a diagrammatic medium. From the task profiles, it was thought extremely important to control the stage in which the Stimuli are assessed due to the drastically different levels of constraints. Customer and carrot projects had remarkably similar information profiles and should be used in preference to generic projects. It was also realised projects with trainee designers as project managers should also be avoided as a point of study and comparison.

Objective G This was addressed in chapter 7 as one of the first major industrial studies of creative Stimuli, conducted using a unique and objective method for idea evaluation. It was shown that, during free-thinking brainstorm sessions, on average the first 20minutes remarkably contained over 80% of Appropriate or Gate Ideas despite the rates being relatively constant up to 30minutes (section 7.3). There was also evidence to suggest the idea generation for technology driven projects differs from market driven projects.

Objective H	Creative Stimuli were shown to be beneficial during group brainstorm in an industrial setting by increasing the rate and number of Appropriate ideas at latter stages of brainstorm sessions (section 7.4).
Objective I	Evidence was provided to further support the TRIZ contradiction matrix/inventive principles and the newly proposed IMCS tool as good examples of current creative Stimuli tools, as Overall these two Guided tools performed the best. There was not enough evidence to suggest one performed markedly better than the other (section 7.5). However, Internally Sourced Stimuli allows for an approach to Retrieve Guided Stimuli automatically saving time and continuing fluency during brainstorming, unachievable by the TRIZ method.

Table 8-1 – Fulfilment of objectives

8.3 Recommendations for industry

The following recommendations are made to the case company, Crown Packaging to help support creativity within their innovation projects:

- Currently, each designer is assigned to a particular business sector in Crown, each having different levels of constraints for their projects. It is proposed that the projects from the various business types are mixed between the various designers, aiding motivation and producing a wider variety of knowledge and skills within the design team.
- It has been observed that each designer spends an overwhelming proportion of time using CAD. Though this is sometimes used as an analysis tool, most uses are simply routine design activities. It is thought that using student and trainee designers to lessen the workload of creating CAD models could create more time for experienced designers to undertake key and creative design activities.
- It is strongly suggested that project managers monitor both the Appropriateness and rate of idea production during idea generation and have prepared Stimuli ready for introduction once a lull is experienced.

- It is also recommended that an automatic Internally Sourced Stimuli system such as the Information Management Creative Stimuli (IMCS) tool is installed to support brainstorm sessions. Other sources of Stimuli should be made available and the use of them encouraged for individual idea generation.

8.4 Recommendations for future work

This study provides a robust and real evaluation of each idea in terms of Appropriateness, Originality and Un-Obviousness which are grounded as important constitutes of the creative output from previous theory (Howard *et al.* 2006; Lopez and Vidal 2006). However, further work needs to be undertaken to value Originality from this perspective as it was observed that many of the developmental ideas between function, behaviour and structure of a concept appeared to be of more value than some of the Original ideas produced starting totally new concepts.

The limitations of the work produced in this thesis are inherent within the engineering design research community. As a young and current ontology-less community, fitting in findings from related studies is difficult as the opportunities and scenarios for each study the will be dramatically different. As an industrially based study, identifying all variables and controlling them is impossible at the current state of the art. The sample sizes produced also cannot provide conclusive proof and relies on knowledgeable interpretation from the embedded researcher.

New experimental/lab based research should be constructed and controlled around such rarely available industrial studies such as this. These lab based studies could use much larger sample sizes and more controlled conditions to help to further verify or disprove the findings from within industry.

The work shows that the different design problems have a large effect, not only on the ideas produced, but the cognitive mechanism by which they are produced. This is highlighted in Figure 7-11, which illustrates clearly how project 1, the only technology driven project, produced relatively high numbers of Appropriate ideas to begin with and far less as time progressed, than the other market driven projects. The

author proposes that this is because one of the 8 design operations in Figure 2-3 becomes most important and is dependent on the nature of the task that has been set.

It is strongly suggested that different studies are carried out using different design tasks and Stimuli types as independent variables. Theses should be assessed in terms of function behaviour and structure. For example, investigating technology-driven tasks, in which, functions will be sought to find uses for an existing behaviour and structure. In market-driven tasks, behaviours and structures will be predominantly sought to provide the functions set by the functional requirements. It is concluded that further studies must be undertaken using the approach generated for this research to asses the effects of setting different types of design problems and relating their inference to a function, behaviour or structure.

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Appendices

The following appendices are complementary to the two descriptive studies and are referred to within the main text of the thesis.

Appendix A – Raw data collected during the information audit in descriptive study 1.

Appendix B – Data from the individual case studies (innovation projects) analysed during descriptive study 2.

Appendix A – Information audit

The following table (Table A-1) is a copy of the recording chart with all sensitive, confidential information removed. The following data can be made available for future research purposes on request to the author (T.J.Howard@bath.ac.uk), or supervisors (S.J.Culley@bath.ac.uk), (E.A.Dekoninck@bath.ac.uk). This will be subject to brief approval by the sponsoring company. The numbers under each heading are binary with the following exceptions:

Project: Number refers to the code assigned to the particular project.
Stage: Ideas stage (1) and Concept stage (2).
Type: Generic project (G), Carrot project (Ca) and Customer project (C).
Business: Food Can (FC), Beverage Can (BC), Speciality Metals (SM), Metal Closures (MC) and Crown Technologies (CT).
Location: Refers to the various desks (Aa-Ag) and rooms (A-F) around the innovation department, also home (H) and out of office (x).
Person: Innovation department designers (A-G), virtual (v) and external (x).

								Mechanism				Source						Type				Carrier											
Date	Time	Project	Stage	Type	Business	Location	Relevant	Pushed	Pulled	Input	Output	Internet	Intranet	Public File store	Local File store	Surrounding	Person	Verbal	Textual	Diagrammatic	Physical	Email	CAD	Imaging	W.P Software	Paper	Photo	Phone	Material	F2F Dialogue	Multiple	Administration
17/10/2005	10:53	1	2	C	FC	Ab	1	1			1			1						1			1									
17/10/2005	11:02	1	2	C	FC		1	1			1			1									1									
17/10/2005	11:10	1	2	C	FC		1	1			1			1						1			1									
17/10/2005	11:17	1	2	C	FC		1	1			1			1						1			1									
17/10/2005	11:33	1	2	C	FC			1		1							V		1			1										
17/10/2005	11:40	1	2	C	FC	Ab		1			1						d	1												1		
17/10/2005	11:48	1	2	C	FC	Ab	1	1			1						V		1			1										
17/10/2005	11:55	1	2	C	FC	Ab	1	1			1				1					1							1					
17/10/2005	12:03	1	2	C	FC	Ab	1		1	1					1					1							1					
17/10/2005	12:03	1	2	C	FC	Ab	1		1	1					1					1					1						1	
17/10/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1						c	1												1		
17/10/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1			1					1						1						1	
17/10/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1					1			1							1					1	
17/10/2005	14:15	1	2	C	FC	Ab		1			1					1			1												1	
17/10/2005	14:15	1	2	C	FC	Ab		1			1					1					1								1		1	
17/10/2005	14:25	35	1	G	FC	Ab		1			1						x	1												1		
17/10/2005	14:25	35	1	G	FC	Ab		1			1					1				1						1					1	
17/10/2005	14:38	35	1	G	FC	Ab	1	1	1	1	1						x	1												1		
17/10/2005	14:38	35	1	G	FC	Ab	1	1	1	1	1			1						1			1								1	
19/10/2005	09:33					Ab			1		1			1					1						1							1
19/10/2005	09:45					Ab		1			1			1						1			1									1
19/10/2005	10:00					Ab		1			1			1						1			1									1
19/10/2005	10:10					Ab			1		1						x	1										1				
19/10/2005	10:18	56	2	G	BC	Ab	1	1	1	1	1						d	1												1		
19/10/2005	10:18	56	2	G	BC	Ab	1	1	1	1	1			1						1			1								1	
19/10/2005	10:27	56	2	G	BC	Ab		1		1							V	1										1				
19/10/2005	10:39					Ab		1			1			1						1			1									
19/10/2005	10:45					Ab		1			1			1					1					1								1
19/10/2005	10:50					Ab			1	1				1					1					1								1
19/10/2005	10:56					Ab		1								1					1								1			
19/10/2005	11:15					Ab		1	1	1	1						c	1												1		
19/10/2005	11:15					Ab		1	1	1	1			1					1						1						1	
19/10/2005	11:15					Ab		1	1	1	1			1						1			1								1	
19/10/2005	11:26					F		1	1	1	1						c	1												1		
19/10/2005	14:35	56	2	G	BC	B	1	1	1	1	1						d,6x	1												1		
19/10/2005	14:35	56	2	G	BC	B	1	1	1	1	1			1						1			1								1	
19/10/2005	14:35	56	2	G	BC	B	1	1	1	1	1					1					1								1		1	
19/10/2005	14:53	56	2	G	BC	B	1	1	1	1	1						d,6x	1												1		
19/10/2005	14:53	56	2	G	BC	B	1	1	1	1	1			1						1			1								1	
19/10/2005	14:53	56	2	G	BC	B	1	1	1	1	1					1					1								1		1	
19/10/2005	15:06	56	2	G	BC	B	1	1	1	1	1						6x	1												1		
19/10/2005	15:06	56	2	G	BC	B	1	1	1	1	1			1						1			1								1	
19/10/2005	15:06	56	2	G	BC	B	1	1	1	1	1					1					1								1		1	
19/10/2005	15:33	56	2	G	BC	B	1	1	1	1	1						6x	1												1		
19/10/2005	15:33	56	2	G	BC	B	1	1	1	1	1			1						1			1								1	
19/10/2005	15:33	56	2	G	BC	B	1	1	1	1	1					1					1								1		1	
19/10/2005	15:42	56	2	G	BC	B	1	1	1	1	1						6x	1												1		
19/10/2005	15:42	56	2	G	BC	B	1	1	1	1	1			1						1			1								1	
19/10/2005	15:42	56	2	G	BC	B	1	1	1	1	1					1					1								1		1	
19/10/2005	15:55					?																										
19/10/2005	16:03					?																										
19/10/2005	16:11					Ab			1	1							c	1												1		
19/10/2005	16:11					Ab			1	1						1					1								1		1	
19/10/2005	16:21					Ab			1	1						1					1								1			
19/10/2005	16:32					F	1	1			1					1					1								1			
19/10/2005	16:55					?																										
19/10/2005	17:05					Ab		1			1			1					1						1								
24/10/2005	14:22	56	2	G	BC	Af	1	1		1	1						df	1												1		
24/10/2005	14:22	56	2	G	BC	Af	1	1		1	1			1						1			1								1	
24/10/2005	14:30	35	1	G	FC	Ab		1			1						V		1			1										1
24/10/2005	14:35	35	1	G	FC	A	1		1	1						1					1								1			
24/10/2005	14:38	35	1	G	FC	Ab	1		1		1			1						1			1									
24/10/2005	14:42	35	1	G	FC	Ab	1		1		1			1						1			1									
24/10/2005	14:46	35	1	G	FC	Ab	1	1			1			1						1			1									
24/10/2005	14:51	35	1	G	FC	Ab	?		1	1							x	1										1				
24/10/2005	14:57	35	1	G	FC	Ab			1		1						a	1												1		1
24/10/2005	15:01	35	1	G	FC	Ab	1	1			1			1						1					1							
24/10/2005	15:29	35	1	G	FC	Ab	1				1			1						1			1									

24/10/2005	15:37	56	2	G	BC	Ab	1	1	1		1					d	1											1		
24/10/2005	15:45	35	1	G	FC	Ab		1	1		1					P	1									1				1
24/10/2005	15:51	35	1	G	FC	Ab	1	1	1		1		1						1			1								1
24/10/2005	16:04	35	1	G	FC	Ab	1	1	1	1	1					x	1											1		
24/10/2005	16:04	35	1	G	FC	Ab	1	1	1	1	1		1						1			1							1	
24/10/2005	16:17	35	1	G	FC	Ab	1	1	1	1	1					x	1											1		
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24/10/2005	16:36	35	1	G	FC	?																								
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24/10/2005	16:45					Ab		1		1						V		1			1								1	1
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26/10/2005	09:41					Ab		1			1					e	1											1		
26/10/2005	09:41					Ab		1			1		1						1				1						1	
26/10/2005	09:50					Ab			1		1					d, e	1											1		1
26/10/2005	10:01	2	1	C	MC	Ab	1		1	1			1						1			1								
26/10/2005	10:17					F			1		1					d	1											1		
26/10/2005	10:30					Ab			1	1			1					1					1							
26/10/2005	10:30					Ab			1	1						V		1			1								1	
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26/10/2005	11:00	56	2	G	BC	B	1	1	1	1	1					d,x,x	1											1		
26/10/2005	11:00	56	2	G	BC	B	1	1	1	1	1				1					1							1		1	
26/10/2005	11:13	56	2	G	BC	B	1	1	1	1	1					d,x,x	1											1		
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26/10/2005	11:56	2	1	C	MC	Ae	1		1		1					e	1											1		
26/10/2005	11:56	2	1	C	MC	Ae	1		1		1		1						1			1							1	
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26/10/2005	14:31	56	2	G	BC	Ad	1	1		1						d	1											1		
26/10/2005	14:31	56	2	G	BC	Ad	1	1		1			1							1							1		1	
26/10/2005	14:39	56	2	G	BC	Ad	1	1	1	1	1					d	1											1		
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26/10/2005	14:39	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
26/10/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1					d	1											1		
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26/10/2005	14:55	56	2	G	BC	Ad	1	1	1	1	1					d	1											1		
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26/10/2005	14:55	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
26/10/2005	15:02					Ab		1	1	1	1					V	1									1				1
26/10/2005	15:21	35	1	G	FC	Ac		1	1	1	1					c	1											1		
26/10/2005	15:50					F	1	1	1	1	1					g	1											1		
26/10/2005	15:50					F	1	1	1	1	1				1					1							1		1	
26/10/2005	16:01					Ab	?	1			1																			1
26/10/2005	16:20					Ab	?		1	1					1				1					1						
26/10/2005	16:30	2	1	C	MC	Ae	1	1	1	1	1					e	1											1		1
26/10/2005	16:30	2	1	C	MC	Ae	1	1	1	1	1		1						1			1							1	1
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04/11/2005	11:02	1	2	C	FC		1	1			1		1									1								
04/11/2005	11:10	1	2	C	FC		1	1			1		1						1			1								
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04/11/2005	11:33	1	2	C	FC			1		1						V		1			1									
04/11/2005	11:40	1	2	C	FC	Ab		1			1					d	1											1		
04/11/2005	11:48	1	2	C	FC	Ab	1	1			1					V		1			1									
04/11/2005	11:55	1	2	C	FC	Ab	1	1			1			1					1						1					
04/11/2005	12:03	1	2	C	FC	Ab	1		1	1				1					1						1					
04/11/2005	12:03	1	2	C	FC	Ab	1		1	1				1					1				1						1	
04/11/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1					c	1											1		
04/11/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1		1					1					1						1	
04/11/2005	14:04	11	2	C	FC	Ac	1	1	1	1	1				1			1						1					1	
04/11/2005	14:15	1	2	C	FC	Ab		1			1				1			1												
04/11/2005	14:15	1	2	C	FC	Ab		1			1				1					1							1		1	

04/11/2005	14:25	35	1	G	FC	Ab		1			1				x	1										1		
04/11/2005	14:25	35	1	G	FC	Ab		1			1			1				1					1				1	
04/11/2005	14:38	35	1	G	FC	Ab	1	1	1	1	1				x	1										1		
04/11/2005	14:38	35	1	G	FC	Ab	1	1	1	1	1		1					1			1						1	
10/11/2005	15:29	35	1	G	FC	Ab	1				1		1					1			1							
10/11/2005	15:37	56	2	G	BC	Ab	1	1	1		1				d	1										1		
10/11/2005	15:45	35	1	G	FC	Ab		1	1		1				P	1								1				1
10/11/2005	15:51	35	1	G	FC	Ab	1	1	1		1		1					1			1							1
10/11/2005	16:04	35	1	G	FC	Ab	1	1	1	1	1				x	1										1		
10/11/2005	16:04	35	1	G	FC	Ab	1	1	1	1	1		1					1			1						1	
10/11/2005	16:17	35	1	G	FC	Ab	1	1	1	1	1				x	1										1		
10/11/2005	16:17	35	1	G	FC	Ab	1	1	1	1	1	1					1					1					1	
10/11/2005	16:27	35	1	G	FC	Ab	1	1		1					x	1										1		
10/11/2005	16:27	35	1	G	FC	Ab	1	1		1				1				1					1				1	
10/11/2005	16:29	35	1	G	FC	Ab	1		1	1					x	1										1		
10/11/2005	16:29	35	1	G	FC	Ab	1		1	1				1					1						1		1	
10/11/2005	16:36	35	1	G	FC	?																						
10/11/2005	16:45					Ab		1		1					x	1										1		1
10/11/2005	16:45					Ab		1		1					V		1			1							1	1
10/11/2005	16:52					Ab		1		1					x	1										1		
11/11/2005	14:22	56	2	G	BC	Af	1	1		1	1				df	1										1		
11/11/2005	14:22	56	2	G	BC	Af	1	1		1	1		1					1			1						1	
11/11/2005	14:30	35	1	G	FC	Ab		1			1				V		1			1								1
11/11/2005	14:35	35	1	G	FC	A	1		1	1				1					1						1			
11/11/2005	14:38	35	1	G	FC	Ab	1		1		1		1					1			1							
11/11/2005	14:42	35	1	G	FC	Ab	1		1		1		1					1			1							
11/11/2005	14:46	35	1	G	FC	Ab	1	1			1		1					1			1							
11/11/2005	14:51	35	1	G	FC	Ab	?		1	1					x	1								1				
11/11/2005	14:57	35	1	G	FC	Ab			1		1				a	1										1		1
11/11/2005	15:01	35	1	G	FC	Ab	1	1			1		1					1				1						
14/11/2005	09:22	35	1	G	FC	Ab	1		1		1				x	1										1		
14/11/2005	09:32					Ab		1		1					x, c	1										1		
14/11/2005	09:41					Ab		1			1				e	1										1		
14/11/2005	09:41					Ab		1			1		1					1				1					1	
14/11/2005	09:50					Ab			1		1				d, e	1										1		1
14/11/2005	10:01	2	1	C	MC	Ab	1		1	1			1					1			1							
14/11/2005	10:17					F			1		1				d	1										1		
14/11/2005	10:30					Ab			1	1			1				1					1						
14/11/2005	10:30					Ab			1	1					V		1			1							1	
14/11/2005	10:48					Aa		1	1		1				a,d,g	1										1		
14/11/2005	11:00	56	2	G	BC	B	1	1	1	1	1				d,x,x	1										1		
14/11/2005	11:00	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
14/11/2005	11:13	56	2	G	BC	B	1	1	1	1	1				d,x,x	1										1		
14/11/2005	11:13	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
14/11/2005	11:13	56	2	G	BC	B	1	1	1	1	1		1					1				1					1	
14/11/2005	11:24	56	2	G	BC	B	1	1	1	1	1				d,x,x	1										1		
14/11/2005	11:24	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
14/11/2005	11:24	56	2	G	BC	B	1	1	1	1	1		1					1				1					1	
14/11/2005	11:47					?																						
14/11/2005	11:56	2	1	C	MC	Ae	1		1		1				e	1										1		
14/11/2005	11:56	2	1	C	MC	Ae	1		1		1		1					1			1						1	
14/11/2005	13:55					?																						
14/11/2005	14:03					?																						
14/11/2005	14:10					?																						
14/11/2005	14:31	56	2	G	BC	Ad	1	1		1					d	1										1		
14/11/2005	14:31	56	2	G	BC	Ad	1	1		1			1						1						1		1	
14/11/2005	14:39	56	2	G	BC	Ad	1	1	1	1	1				d	1										1		
14/11/2005	14:39	56	2	G	BC	Ad	1	1	1	1	1			1					1						1		1	
14/11/2005	14:39	56	2	G	BC	Ad	1	1	1	1	1		1					1			1						1	
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1				d	1										1		
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1			1					1						1		1	
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1		1					1			1						1	
14/11/2005	14:55	56	2	G	BC	Ad	1	1	1	1	1				d	1										1		
14/11/2005	14:55	56	2	G	BC	Ad	1	1	1	1	1			1					1						1		1	
14/11/2005	14:55	56	2	G	BC	Ad	1	1	1	1	1		1					1			1						1	
14/11/2005	15:02					Ab		1	1	1	1				V	1								1				1
14/11/2005	15:21	35	1	G	FC	Ac		1	1	1	1				c	1										1		
14/11/2005	15:50					F	1	1	1	1	1				g	1										1		
14/11/2005	15:50					F	1	1	1	1	1			1					1						1		1	
14/11/2005	16:01					Ab	?	1			1																	1
14/11/2005	16:20					Ab	?		1	1				1				1					1					
14/11/2005	16:30	2	1	C	MC	Ae	1	1	1	1	1				e	1										1		1
14/11/2005	16:30	2	1	C	MC	Ae	1	1	1	1	1		1					1			1						1	1
14/11/2005	16:39					Ac		1	1	1	1				c	1										1		

14/11/2005	16:51					?																									
18/11/2005	09:33					Ab			1		1			1					1						1						1
18/11/2005	09:45					Ab		1			1			1						1			1								1
18/11/2005	10:00					Ab		1			1			1						1			1								1
18/11/2005	10:10					Ab			1		1						x	1									1				
18/11/2005	10:18	56	2	G	BC	Ab	1	1	1	1	1						d	1											1		
18/11/2005	10:18	56	2	G	BC	Ab	1	1	1	1	1			1						1			1							1	
18/11/2005	10:27	56	2	G	BC	Ab		1		1							V	1									1				
18/11/2005	10:39					Ab		1			1			1						1			1								
18/11/2005	10:45					Ab		1			1			1					1						1						1
18/11/2005	10:50					Ab			1	1				1					1						1						1
18/11/2005	10:56					Ab		1								1					1							1			
18/11/2005	11:15					Ab		1	1	1	1						c	1											1		
18/11/2005	11:15					Ab		1	1	1	1			1					1						1					1	
18/11/2005	11:15					Ab		1	1	1	1			1						1			1							1	
18/11/2005	11:26					F		1	1	1	1						c	1											1		
18/11/2005	14:35	56	2	G	BC	B	1	1	1	1	1						d,6x	1											1		
18/11/2005	14:35	56	2	G	BC	B	1	1	1	1	1			1						1			1							1	
18/11/2005	14:35	56	2	G	BC	B	1	1	1	1	1					1					1							1		1	
18/11/2005	14:53	56	2	G	BC	B	1	1	1	1	1						d,6x	1											1		
18/11/2005	14:53	56	2	G	BC	B	1	1	1	1	1			1						1			1							1	
18/11/2005	14:53	56	2	G	BC	B	1	1	1	1	1					1					1							1		1	
18/11/2005	15:06	56	2	G	BC	B	1	1	1	1	1						6x	1											1		
18/11/2005	15:06	56	2	G	BC	B	1	1	1	1	1			1						1			1							1	
18/11/2005	15:06	56	2	G	BC	B	1	1	1	1	1					1					1							1		1	
18/11/2005	15:33	56	2	G	BC	B	1	1	1	1	1						6x	1											1		
18/11/2005	15:33	56	2	G	BC	B	1	1	1	1	1			1						1			1							1	
18/11/2005	15:33	56	2	G	BC	B	1	1	1	1	1					1					1							1		1	
18/11/2005	15:42	56	2	G	BC	B	1	1	1	1	1						6x	1					1						1		
18/11/2005	15:42	56	2	G	BC	B	1	1	1	1	1			1						1			1							1	
18/11/2005	15:42	56	2	G	BC	B	1	1	1	1	1					1					1							1		1	
18/11/2005	15:55					?																									
18/11/2005	16:03					?																									
18/11/2005	16:11					Ab			1	1							c	1											1		
18/11/2005	16:11					Ab			1	1						1					1							1		1	
18/11/2005	16:21					Ab			1	1						1					1							1			
18/11/2005	16:32					F	1	1			1					1					1							1			
18/11/2005	16:55					?																									
18/11/2005	17:05					Ab		1			1			1					1						1						
17/10/2005	09:54	11	2	C	FC	Ac			1		1						x	1									1				
17/10/2005	09:54	11	2	C	FC	Ac			1		1		1						1						1					1	
17/10/2005	10:07	11	2	C	FC	Ac	1	1			1			1						1			1								
17/10/2005	10:13	11	2	C	FC	Ac	1	1			1			1						1				1							
17/10/2005	10:28	47	1	C	FC	Af			1	1							f	1											1		
17/10/2005	10:28	47	1	C	FC	Af			1	1		1							1						1					1	
17/10/2005	10:54	11	2	C	FC	Ac	1		1	1				1						1			1								
17/10/2005	11:04	11	2	C	FC	Ae					1						e	1											1		
17/10/2005	11:11	11	2	C	FC			1			1						V		1			1									
17/10/2005	11:25	11	2	C	FC	Ac	1	1			1			1						1					1						
17/10/2005	11:34	11	2	C	FC	Ac	1			1							P	1									1				
17/10/2005	11:42	11	2	C	FC	Ac	1	1			1			1						1			1								
17/10/2005	11:49	11	2	C	FC	Ac	1		1		1				1				1						1						
17/10/2005	11:57	11	2	C	FC	Ac	1		1	1				1						1			1								
17/10/2005	14:06	11	2	C	FC	Ac	1	1	1		1						bx	1											1		
17/10/2005	14:06	11	2	C	FC	Ac	1	1	1		1			1						1					1					1	
17/10/2005	14:06	11	2	C	FC	Ac	1	1	1		1			1						1						1				1	
17/10/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1						bx	1											1		
17/10/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1			1						1						1				1	
17/10/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1			1						1				1						1	
17/10/2005	14:30	11	2	C	FC	Ac	1		1	1							x	1											1		
17/10/2005	14:41	11	2	C	FC	Ac	1	1			1			1						1					1						
19/10/2005	09:34					B		1	1	1	1						x,x	1											1		1
19/10/2005	09:34					B		1	1	1	1			1					1						1					1	1
19/10/2005	09:46					B		1	1	1	1						x,x	1											1		1
19/10/2005	09:46					B		1	1	1	1			1					1						1					1	1
19/10/2005	10:01					B		1	1	1	1						x,x	1											1		1
19/10/2005	10:01					B		1	1	1	1			1					1						1					1	1
19/10/2005	10:12					B		1	1	1	1						x,x	1											1		1
19/10/2005	10:12					B		1	1	1	1			1					1						1					1	1
19/10/2005	10:20					B		1	1	1	1						x,x	1											1		1
19/10/2005	10:20					B		1	1	1	1			1					1						1					1	1
19/10/2005	10:32					B		1	1	1	1						x,x	1											1		1
19/10/2005	10:32					B		1	1	1	1			1					1						1					1	1
19/10/2005	10:40					B		1	1	1	1						x,x	1											1		1

19/10/2005	10:40					B		1	1	1	1			1					1						1						1	1
19/10/2005	10:46					Ac			1	1																						
19/10/2005	10:51					Ac				1							V		1			1										1
19/10/2005	11:02					Ac		1			1						V		1			1										1
19/10/2005	11:16					Ac	1	1	1	1	1						b	1												1		
19/10/2005	11:16					Ac	1	1	1	1	1			1						1			1								1	
19/10/2005	11:28					F		1	1	1	1						c	1												1		
19/10/2005	14:41	57	1	C	FC	Ac	1		1	1				1						1				1								
19/10/2005	14:53	57	1	C	FC	Ac	1		1	1				1						1					1							
19/10/2005	15:16	57	1	C	FC	Ac			1	1							f	1												1		
19/10/2005	15:16	57	1	C	FC	Ac			1	1						1				1						1					1	
19/10/2005	15:34	49	1	C	FC	Ac	1		1	1				1						1			1									
19/10/2005	14:24					Ac			1	1						1					1					1						1
19/10/2005	15:58					Ac			1	1						1					1					1						1
19/10/2005	16:03					Ac			1	1						1					1					1						1
19/10/2005	16:12					Ac		1			1						V		1			1										1
19/10/2005	16:22					Ac		1	1	1	1						x	1										1				1
19/10/2005	16:22					Ac		1	1	1	1				1				1							1					1	1
19/10/2005	16:35					H																										
24/10/2005	15:40					H																										
26/10/2005	09:23					Ac	?	1		1							V		1			1										1
26/10/2005	09:33					Ac	?		1	1							x	1												1		1
26/10/2005	09:33					Ac	?		1	1					1					1					1						1	1
26/10/2005	09:43					Ac	?	1			1						V			1		1										1
26/10/2005	09:52					Ac	?	1		1				1						1		1										1
26/10/2005	10:08	32	1	G	CT	Ac	1		1		1				1					1				1								
26/10/2005	10:08	32	1	G	CT	Ac	1		1		1					1				1							1				1	
26/10/2005	10:19	38	1	Ca	SM	Ag	1		1		1						g	1												1		
26/10/2005	10:19	38	1	Ca	SM	Ag	1		1		1					1				1						1					1	
26/10/2005	10:35					?																										
26/10/2005	10:50					?																										
26/10/2005	11:03					Ac											x	1												1		
26/10/2005	11:16					?																										
26/10/2005	11:24					?																										
26/10/2005	11:48					Ac		1		1							V		1			1										1
26/10/2005	11:57					Ac		1	1	1						1					1					1						1
26/10/2005	13:55					Ac		1			1						V		1			1										1
26/10/2005	14:03					?																										
26/10/2005	14:23					?																										
26/10/2005	14:32					?																										
26/10/2005	15:45					?																										
26/10/2005	15:55					?																										
26/10/2005	16:03	?	?	?	?	B	1	1	1	1	1						x,x	1												1		1
26/10/2005	16:03	?	?	?	?	B	1	1	1	1	1					1					1								1		1	1
26/10/2005	16:21					B	1	1	1	1	1						x,x	1												1		1
26/10/2005	16:32					x																										
26/10/2005	16:46					Ac	1		1	1							P	1										1				
26/10/2005	16:52					Ac											x	1										1				
26/10/2005	16:52					Ac										1			1							1					1	
04/11/2005	09:54	11	2	C	FC	Ac			1		1						x	1										1				
04/11/2005	09:54	11	2	C	FC	Ac			1		1		1						1						1						1	
04/11/2005	10:07	11	2	C	FC	Ac	1	1			1			1						1			1									
04/11/2005	10:13	11	2	C	FC	Ac	1	1			1			1						1				1								
04/11/2005	10:28	47	1	C	FC	Af			1	1							f	1												1		
04/11/2005	10:28	47	1	C	FC	Af			1	1		1							1						1						1	
04/11/2005	10:54	11	2	C	FC	Ac	1		1	1				1						1			1									
04/11/2005	11:04	11	2	C	FC	Ae					1						e	1												1		
04/11/2005	11:11	11	2	C	FC			1			1						V		1			1										
04/11/2005	11:25	11	2	C	FC	Ac	1	1			1			1						1					1							
04/11/2005	11:34	11	2	C	FC	Ac	1			1							P	1										1				
04/11/2005	11:42	11	2	C	FC	Ac	1	1			1			1						1			1									
04/11/2005	11:49	11	2	C	FC	Ac	1		1		1				1				1						1							
04/11/2005	11:57	11	2	C	FC	Ac	1		1	1				1						1			1									
04/11/2005	14:06	11	2	C	FC	Ac	1	1	1		1						bx	1												1		
04/11/2005	14:06	11	2	C	FC	Ac	1	1	1		1			1						1					1						1	
04/11/2005	14:06	11	2	C	FC	Ac	1	1	1		1			1						1						1					1	
04/11/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1						bx	1												1		
04/11/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1			1						1						1					1	
04/11/2005	14:18	11	2	C	FC	Ac	1	1	1	1	1			1						1				1							1	
04/11/2005	14:30	11	2	C	FC	Ac	1		1	1							x	1												1		
04/11/2005	14:41	11	2	C	FC	Ac	1	1			1			1						1					1							
10/11/2005	15:40					H																										
14/11/2005	09:23					Ac	?	1		1							V		1			1										1
14/11/2005	09:33					Ac	?		1	1							x	1												1		1

14/11/2005	09:33					Ac	?		1	1			1					1					1						1	1
14/11/2005	09:43					Ac	?	1			1				V			1		1										1
14/11/2005	09:52					Ac	?	1		1		1						1		1										1
14/11/2005	10:08	32	1	G	CT	Ac	1		1		1		1					1				1								
14/11/2005	10:08	32	1	G	CT	Ac	1		1		1			1				1							1				1	
14/11/2005	10:19	38	1	Ca	SM	Ag	1		1		1				g	1												1		
14/11/2005	10:19	38	1	Ca	SM	Ag	1		1		1			1				1						1					1	
14/11/2005	10:35					?																								
14/11/2005	10:50					?																								
14/11/2005	11:03					Ac									x	1												1		
14/11/2005	11:16					?																								
14/11/2005	11:24					?																								
14/11/2005	11:48					Ac		1		1					V		1			1										1
14/11/2005	11:57					Ac		1	1	1				1					1					1						1
14/11/2005	13:55					Ac		1			1				V		1			1										1
14/11/2005	14:03					?																								
14/11/2005	14:23					?																								
14/11/2005	14:32					?																								
14/11/2005	15:45					?																								
14/11/2005	15:55					?																								
14/11/2005	16:03	?	?	?	?	B	1	1	1	1	1				x,x	1												1		1
14/11/2005	16:03	?	?	?	?	B	1	1	1	1	1			1					1								1		1	1
14/11/2005	16:21					B	1	1	1	1	1				x,x	1												1		1
14/11/2005	16:32					x																								
14/11/2005	16:46					Ac	1		1	1					P	1										1				
14/11/2005	16:52					Ac									x	1										1				
14/11/2005	16:52					Ac								1			1							1					1	
18/11/2005	09:34					B		1	1	1	1				x,x	1												1		1
18/11/2005	09:34					B		1	1	1	1	1					1						1						1	1
18/11/2005	09:46					B		1	1	1	1				x,x	1												1		1
18/11/2005	09:46					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:01					B		1	1	1	1				x,x	1												1		1
18/11/2005	10:01					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:12					B		1	1	1	1				x,x	1												1		1
18/11/2005	10:12					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:20					B		1	1	1	1				x,x	1												1		1
18/11/2005	10:20					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:32					B		1	1	1	1				x,x	1												1		1
18/11/2005	10:32					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:40					B		1	1	1	1				x,x	1												1		1
18/11/2005	10:40					B		1	1	1	1	1					1						1						1	1
18/11/2005	10:46					Ac			1	1																				
18/11/2005	10:51					Ac				1					V		1			1										1
18/11/2005	11:02					Ac		1			1				V		1			1										1
18/11/2005	11:16					Ac	1	1	1	1	1				b	1												1		
18/11/2005	11:16					Ac	1	1	1	1	1	1						1			1								1	
18/11/2005	11:28					F		1	1	1	1				c	1												1		
18/11/2005	14:41	57	1	C	FC	Ac	1		1	1		1						1				1								
18/11/2005	14:53	57	1	C	FC	Ac	1		1	1		1						1					1							
18/11/2005	15:16	57	1	C	FC	Ac			1	1					f	1												1		
18/11/2005	15:16	57	1	C	FC	Ac			1	1				1				1						1					1	
18/11/2005	15:34	49	1	C	FC	Ac	1		1	1		1						1			1									
18/11/2005	15:50					Ac			1	1				1					1					1						1
18/11/2005	15:58					Ac			1	1				1					1					1						1
18/11/2005	16:03					Ac			1	1				1					1					1						1
18/11/2005	16:12					Ac		1			1				V		1			1										1
18/11/2005	16:22					Ac		1	1	1	1				x	1										1				1
18/11/2005	16:22					Ac		1	1	1	1		1				1							1					1	1
18/11/2005	16:35					H																								
17/10/2005	10:56					Ad									x	1												1		
17/10/2005	10:56					Ad								1					1								1		1	
17/10/2005	11:05					?																								
17/10/2005	11:12					?																								
17/10/2005	11:26	56	2	G	BC	Ad			1	1					V		1			1										
17/10/2005	11:36	56	2	G	BC	Ad	1	1			1	1					1						1							
17/10/2005	11:43	56	2	G	BC	Ab		1	1	1	1			1				1				1								
17/10/2005	11:50	56	2	G	BC	Ab	1		1	1		1					1						1							
17/10/2005	11:59	56	2	G	BC	o																								
17/10/2005	14:09	56	2	G	BC	Ad		1			1																			
17/10/2005	14:21	56	2	G	BC	Ad	1		1	1		1						1			1									
17/10/2005	14:31	56	2	G	BC	Ad	2	1			1	1						1			1									
17/10/2005	14:42																													
19/10/2005	09:36	56	2	G	BC	Ad	1		1	1		1						1			1									
19/10/2005	09:47	56	2	G	BC	Ad	1		1	1		1						1			1									

19/10/2005	10:03	56	2	G	BC	Ad	1		1	1		1						1			1							
19/10/2005	10:13	56	2	G	BC	Ad	1	1			1				b	1										1		
19/10/2005	10:13	56	2	G	BC	Ad	1	1			1	1						1			1						1	
19/10/2005	10:22	56	2	G	BC	Ad	1	1	1	1	1				b	1										1		
19/10/2005	10:22	56	2	G	BC	Ad	1	1	1	1	1			1				1					1				1	
19/10/2005	10:33	56	2	G	BC	Ad	1		1	1		1						1			1							
19/10/2005	10:40	56	2	G	BC	Ad	1		1	1		1						1			1							
19/10/2005	10:47					R																						
19/10/2005	10:52					R																						
19/10/2005	11:03	56	2	G	BC	Ad	1		1	1		1						1			1							
19/10/2005	11:17	56	2	G	BC	Ad	1	1			1		1					1					1					
19/10/2005	11:29	56	2	G	BC	Ad	1		1	1		1						1			1							
19/10/2005	14:47	56	2	G	BC	B	1	1	1	1	1				b,6x	1										1		
19/10/2005	14:47	56	2	G	BC	B	1	1	1	1	1	1						1			1						1	
19/10/2005	14:47	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
19/10/2005	14:55	56	2	G	BC	B	1	1	1	1	1				b,6x	1										1		
19/10/2005	14:55	56	2	G	BC	B	1	1	1	1	1	1						1			1						1	
19/10/2005	14:55	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
19/10/2005	15:18					H																						
24/10/2005	14:27	56	2	G	BC	Ad	1	1	1	1	1				x	1								1				?
24/10/2005	14:27	56	2	G	BC	Ad	1	1	1	1	1			1					1						1		1	?
24/10/2005	14:32						?	1		1					V		1			1								
24/10/2005	14:36	56	2	G	BC	Ad		1			1				P	1								1				
24/10/2005	14:39	56	2	G	BC	Ad	?		1	1					V		1			1								
24/10/2005	14:42	56	2	G	BC	Ad			1	1			1				1			1								1
24/10/2005	14:47	56	2	G	BC	Ad		1			1		1				1			1								1
24/10/2005	14:52	56	2	G	BC	Ad	1	1			1	1					1					1						
24/10/2005	14:59	56	2	G	BC	?																						
24/10/2005	15:41	56	2	G	BC	Ab	1		1		1				b	1										1		
24/10/2005	15:47	56	2	G	BC	Ad	1		1		1	1						1			1							
24/10/2005	15:59	56	2	G	BC	D																						
24/10/2005	16:11	56	2	G	BC	Ad	1		1		1	1						1			1							
24/10/2005	16:21	56	2	G	BC	Ad	1		1	1	1	1						1			1							
24/10/2005	16:31	56	2	G	BC	Ad	?	?																				
24/10/2005	16:38	56	2	G	BC	Ad	1				1	1						1			1							
24/10/2005	16:47	56	2	G	BC	?																						
24/10/2005	16:53	56	2	G	BC	?																						
26/10/2005	09:24					?																						
26/10/2005	09:34	53	1	G	AE	Ad		1		1					V			1		1								1
26/10/2005	09:44	53	1	G	AE	Ad		1		1					x	1										1		1
26/10/2005	09:53	53	1	G	AE	?																						
26/10/2005	10:10					?																						
26/10/2005	10:23					?																						
26/10/2005	10:36	56	2	G	BC	Ad	1	1		1					V		1			1								1
26/10/2005	10:50	56	2	G	BC	Ab	1	1	1	1	1				b	1										1		
26/10/2005	11:04	56	2	G	BC	B	1	1	1	1	1				b,x,x	1										1		
26/10/2005	11:04	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
26/10/2005	11:16	56	2	G	BC	B	1	1	1	1	1				b,x,x	1										1		
26/10/2005	11:16	56	2	G	BC	B	1	1	1	1	1	1						1				1					1	
26/10/2005	11:16	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
26/10/2005	11:25	56	2	G	BC	B	1	1	1	1	1				b,x,x	1										1		
26/10/2005	11:25	56	2	G	BC	B	1	1	1	1	1	1						1				1					1	
26/10/2005	11:25	56	2	G	BC	B	1	1	1	1	1			1					1						1		1	
26/10/2005	11:49	56	2	G	BC	Ad	1		1	1		1					1					1						1
26/10/2005	11:58	56	2	G	BC	Ad	1	1			1	1					1					1						
26/10/2005	13:57	56	2	G	BC	Ad	1		1	1		1						1			1							
26/10/2005	14:05	56	2	G	BC	Ad	1		1	1		1						1			1							
26/10/2005	14:23	56	2	G	BC	Ad	1		1		1	1						1			1							
26/10/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1				b	1										1		
26/10/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1	1						1			1						1	
26/10/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1			1					1		1				1		1	
26/10/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1				b	1										1		
26/10/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1	1						1			1						1	
26/10/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1			1					1		1				1		1	
26/10/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1				b	1										1		
26/10/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1	1						1			1						1	
26/10/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1			1					1		1				1		1	
26/10/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1				b	1										1		
26/10/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1	1						1			1						1	
26/10/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1			1					1		1				1		1	
26/10/2005	15:10	56	2	G	BC	Ad	1		1		1	1						1			1							
26/10/2005	15:45	56	2	G	BC	Ad			1	1					V		1			1								
26/10/2005	15:55					?																						
26/10/2005	16:06	56	2	G	BC	Ad	1		1	1		1						1			1							

26/10/2005	16:06	56	2	G	BC	Ad	1		1	1					1				1						1				1	
26/10/2005	16:23	56	2	G	BC	Ad	1	1		1					1				1						1					
26/10/2005	16:32	56	2	G	BC	Ad,D			1	1	1				1					1							1			
26/10/2005	16:47					?																								
26/10/2005	16:59					Ad	1	1			1	1						1						1						
04/11/2005	10:56					Ad										x	1											1		
04/11/2005	10:56					Ad									1					1							1		1	
04/11/2005	11:05					?																								
04/11/2005	11:12					?																								
04/11/2005	11:26	56	2	G	BC	Ad			1	1						V		1			1									
04/11/2005	11:36	56	2	G	BC	Ad	1	1			1		1					1						1						
04/11/2005	11:43	56	2	G	BC	Ab		1	1	1	1				1				1				1							
04/11/2005	11:50	56	2	G	BC	Ab	1		1	1			1					1						1						
04/11/2005	11:59	56	2	G	BC	o																								
04/11/2005	14:09	56	2	G	BC	Ad		1			1																			
04/11/2005	14:21	56	2	G	BC	Ad	1		1	1			1						1			1								
04/11/2005	14:31	56	2	G	BC	Ad	2	1			1		1						1			1								
04/11/2005	14:42																													
10/11/2005	15:41	56	2	G	BC	Ab	1		1		1					b	1											1		
10/11/2005	15:47	56	2	G	BC	Ad	1		1		1		1						1			1								
10/11/2005	15:59	56	2	G	BC	D																								
10/11/2005	16:11	56	2	G	BC	Ad	1		1		1		1						1			1								
10/11/2005	16:21	56	2	G	BC	Ad	1		1	1	1		1						1			1								
10/11/2005	16:31	56	2	G	BC	Ad	?	?																						
10/11/2005	16:38	56	2	G	BC	Ad	1				1		1						1			1								
10/11/2005	16:47	56	2	G	BC	?																								
10/11/2005	16:53	56	2	G	BC	?																								
11/11/2005	14:27	56	2	G	BC	Ad	1	1	1	1	1					x	1									1				?
11/11/2005	14:27	56	2	G	BC	Ad	1	1	1	1	1				1					1							1		1	?
11/11/2005	14:32						?	1		1						V		1			1									
11/11/2005	14:36	56	2	G	BC	Ad		1			1					P	1									1				
11/11/2005	14:39	56	2	G	BC	Ad	?		1	1						V		1			1									
11/11/2005	14:42	56	2	G	BC	Ad			1	1				1				1			1									1
11/11/2005	14:47	56	2	G	BC	Ad		1			1			1				1			1									1
11/11/2005	14:52	56	2	G	BC	Ad	1	1			1		1					1						1						
11/11/2005	14:59	56	2	G	BC	?																								
14/11/2005	09:24					?																								
14/11/2005	09:34	53	1	G	AE	Ad		1		1						V			1		1									1
14/11/2005	09:44	53	1	G	AE	Ad		1		1						x	1											1		1
14/11/2005	09:53	53	1	G	AE	?																								
14/11/2005	10:10					?																								
14/11/2005	10:23					?																								
14/11/2005	10:36	56	2	G	BC	Ad	1	1		1						V		1			1									1
14/11/2005	10:50	56	2	G	BC	Ab	1	1	1	1	1					b	1											1		
14/11/2005	11:04	56	2	G	BC	B	1	1	1	1	1					b,x,x	1											1		
14/11/2005	11:04	56	2	G	BC	B	1	1	1	1	1				1					1							1		1	
14/11/2005	11:16	56	2	G	BC	B	1	1	1	1	1					b,x,x	1											1		
14/11/2005	11:16	56	2	G	BC	B	1	1	1	1	1		1						1					1					1	
14/11/2005	11:16	56	2	G	BC	B	1	1	1	1	1				1					1							1		1	
14/11/2005	11:25	56	2	G	BC	B	1	1	1	1	1					b,x,x	1											1		
14/11/2005	11:25	56	2	G	BC	B	1	1	1	1	1		1						1					1					1	
14/11/2005	11:25	56	2	G	BC	B	1	1	1	1	1				1					1							1		1	
14/11/2005	11:49	56	2	G	BC	Ad	1		1	1			1					1						1						1
14/11/2005	11:58	56	2	G	BC	Ad	1	1			1		1					1						1						
14/11/2005	13:57	56	2	G	BC	Ad	1		1	1			1						1			1								
14/11/2005	14:05	56	2	G	BC	Ad	1		1	1			1						1			1								
14/11/2005	14:23	56	2	G	BC	Ad	1		1		1		1						1			1								
14/11/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1					b	1											1		
14/11/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
14/11/2005	14:33	56	2	G	BC	Ad	1	1	1	1	1				1					1		1					1		1	
14/11/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1					b	1											1		
14/11/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
14/11/2005	14:40	56	2	G	BC	Ad	1	1	1	1	1				1					1		1					1		1	
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1					b	1											1		
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
14/11/2005	14:45	56	2	G	BC	Ad	1	1	1	1	1				1					1		1					1		1	
14/11/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1					b	1											1		
14/11/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1		1						1			1							1	
14/11/2005	14:56	56	2	G	BC	Ad	1	1	1	1	1				1					1		1					1		1	
14/11/2005	15:10	56	2	G	BC	Ad	1		1		1		1						1			1								
14/11/2005	15:45	56	2	G	BC	Ad			1	1						V		1			1									
14/11/2005	15:55					?																								
14/11/2005	16:06	56	2	G	BC	Ad	1		1	1			1						1			1								
14/11/2005	16:06	56	2	G	BC	Ad	1		1	1					1				1						1				1	

14/11/2005	16:23	56	2	G	BC	Ad	1	1		1					1				1						1						
14/11/2005	16:32	56	2	G	BC	Ad,D			1	1	1				1					1								1			
14/11/2005	16:47					?																									
14/11/2005	16:59					Ad	1	1			1	1						1						1							
18/11/2005	09:36	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	09:47	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	10:03	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	10:13	56	2	G	BC	Ad	1	1			1					b	1												1		
18/11/2005	10:13	56	2	G	BC	Ad	1	1			1		1						1			1								1	
18/11/2005	10:22	56	2	G	BC	Ad	1	1	1	1	1					b	1												1		
18/11/2005	10:22	56	2	G	BC	Ad	1	1	1	1	1				1				1						1					1	
18/11/2005	10:33	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	10:40	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	10:47					R																									
18/11/2005	10:52					R																									
18/11/2005	11:03	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	11:17	56	2	G	BC	Ad	1	1			1			1					1						1						
18/11/2005	11:29	56	2	G	BC	Ad	1		1	1			1						1			1									
18/11/2005	14:47	56	2	G	BC	B	1	1	1	1	1					b,6x	1												1		
18/11/2005	14:47	56	2	G	BC	B	1	1	1	1	1		1						1			1								1	
18/11/2005	14:47	56	2	G	BC	B	1	1	1	1	1				1					1								1		1	
18/11/2005	14:55	56	2	G	BC	B	1	1	1	1	1					b,6x	1												1		
18/11/2005	14:55	56	2	G	BC	B	1	1	1	1	1		1						1			1								1	
18/11/2005	14:55	56	2	G	BC	B	1	1	1	1	1				1					1								1		1	
18/11/2005	15:18					H																									
17/10/2005	10:32	38	1	Ca	SM	Ae	1	1			1		1						1			1									
17/10/2005	10:32	38	1	Ca	SM	Ae	1	1			1				1					1								1		1	
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17/10/2005	11:05	38	1	Ca	SM	Ae		1		1						c	1												1		
17/10/2005	11:12	38	1	Ca	SM	Ae		1			1		1						1				1								
17/10/2005	11:28	38	1	Ca	SM	Ae		1			1					V		1			1										
17/10/2005	11:37	38	1	Ca	SM	Ae		1			1					V		1			1										
17/10/2005	11:45	38	1	Ca	SM	Ae	1	1			1		1						1				1								
17/10/2005	11:52	38	1	Ca	SM	Ae	1	1			1		1						1				1								
17/10/2005	11:59	38	1	Ca	SM	Ae	1		1	1			1						1				1								
17/10/2005	14:10	38	1	Ca	SM	Ag	1	1			1					g	1												1		
17/10/2005	14:22	38	1	Ca	SM	Ae	1	1			1		1						1			1									
17/10/2005	14:33	38	1	Ca	SM	Ae	1	1		1						g	1												1		
17/10/2005	14:33	38	1	Ca	SM	Ae	1	1		1			1						1				1							1	
19/10/2005	09:38					Ae			1	1				1				1			1										1
19/10/2005	09:56					Ae			1	1					1			1							1						1
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19/10/2005	10:14	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	10:24	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	10:34	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	10:42	21	1	Ca	SM	Ae	1		1	1			1						1			1									1
19/10/2005	10:48	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	10:53	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	11:04	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	11:19	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	11:31					?																									
19/10/2005	14:48	21	1	Ca	SM	Ae	1		1	1			1						1			1									
19/10/2005	14:58					Ae			1	1					1					1						1					
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19/10/2005	15:19	21	1	Ca	SM	Ae	1		1	1			1						1			1								1	
19/10/2005	15:35					A			1	1										1											1
19/10/2005	15:50	21	1	Ca	SM	Ae	1		1	1			1						1			1									
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19/10/2005	16:15					Ae		1			1			1				1			1										1
19/10/2005	16:24	21	1	Ca	SM	Ae	1		1	1			1						1			1									
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19/10/2005	16:58					C	?	1	1	1	1					P	1										1				
24/10/2005	15:33	21	1	Ca	SM	Ae	1		1		1		1						1			1									
24/10/2005	15:42	21	1	Ca	SM	Ae	1		1	1			1						1			1									
24/10/2005	15:49	21	1	Ca	SM	Ae	1		1	1			1						1			1									
24/10/2005	16:01	38	1	Ca	SM	Ag	1	1		1						g	1												1		
24/10/2005	16:01	38	1	Ca	SM	Ag	1	1		1			1						1				1							1	
24/10/2005	16:13	38	1	Ca	SM	Ag	1	1		1						g	1												1		
24/10/2005	16:13	38	1	Ca	SM	Ag	1	1		1			1						1				1							1	
24/10/2005	16:23	38	1	Ca	SM	Ae	1		1	1			1						1				1								
24/10/2005	16:33	38	1	Ca	SM	Ae	1		1	1			1						1				1								1
24/10/2005	16:40	21	1	Ca	SM	Ae	1		1	1			1						1			1									
24/10/2005	16:48	38	1	Ca	SM	Ag	1	1		1						g	1												1		

24/10/2005	16:48	38	1	Ca	SM	Ag	1	1		1		1						1					1			1	
24/10/2005	16:54	38	1	Ca	SM	Ag	1	1	1	1					g	1									1		
24/10/2005	16:54	38	1	Ca	SM	Ag	1	1	1	1		1						1					1			1	
26/10/2005	09:25	21	1	Ca	SM	Ag	?	1		1	1				g	1									1		
26/10/2005	09:25	21	1	Ca	SM	Ag	?	1		1	1	1						1					1			1	
26/10/2005	09:36	2	1	C	MC	Ab	1	1		1					b	1									1		
26/10/2005	09:36	2	1	C	MC	Ab	1	1		1		1						1					1			1	
26/10/2005	09:45	2	1	C	MC	Ab	1	1		1					B			1		1							
26/10/2005	09:45	2	1	C	MC	Ab	1	1		1		1						1			1					1	
26/10/2005	09:54	2	1	C	MC	Ab	1	1		1					b	1							1				1
26/10/2005	10:10	2	1	C	MC	Ae	1	1		1	1							1		1	1						
26/10/2005	10:24					Ae			1		1	1					1						1				1
26/10/2005	10:38					Ab		1		1					b	1									1		1
26/10/2005	10:52	2	1	C	MC	Ae	1		1		1																1
26/10/2005	11:06	2	1	C	MC	Ae	1	1			1				g	1									1		
26/10/2005	11:06	2	1	C	MC	Ae	1	1			1	1						1			1					1	
26/10/2005	11:17					Ae		1		1				1					1					1			
26/10/2005	11:26					Ae		1	1		1				a	1									1		
26/10/2005	11:50	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	12:00	2	1	C	MC	Ae	1	1			1				b	1									1		
26/10/2005	12:00	2	1	C	MC	Ae	1	1			1	1						1			1						
26/10/2005	13:59	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	14:06	2	1	C	MC	Ae		1	1		1																
26/10/2005	14:25	2	1	C	MC	Ae	1		1		1	1						1			1						
26/10/2005	14:35	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	14:41	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	14:46	2	1	C	MC	Ae	?	1		1					V		1			1							?
26/10/2005	14:59	2	1	C	MC	Ae	1		1		1	1						1			1						
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26/10/2005	15:56	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	16:07	2	1	C	MC	Ae	1		1	1		1						1			1						
26/10/2005	16:27	2	1	C	MC	Ae	1	1	1	1	1				b	1									1		
26/10/2005	16:27	2	1	C	MC	Ae	1	1	1	1	1	1						1			1					1	
26/10/2005	16:35	2	1	C	MC	Ae	1	1		1	?	1						1					1				
26/10/2005	16:48	2	1	C	MC	Ae	1		1	1		1						1			1						1
26/10/2005	17:01	2	1	C	MC	Ae		1		1			1				1			1							1
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04/11/2005	10:32	38	1	Ca	SM	Ae	1	1			1			1					1					1		1	
04/11/2005	10:57	38	1	Ca	SM	Ae	1	1			1	1						1				1					
04/11/2005	11:05	38	1	Ca	SM	Ae		1		1					c	1									1		
04/11/2005	11:12	38	1	Ca	SM	Ae		1			1	1						1				1					
04/11/2005	11:28	38	1	Ca	SM	Ae		1			1				V		1			1							
04/11/2005	11:37	38	1	Ca	SM	Ae		1			1				V		1			1							
04/11/2005	11:45	38	1	Ca	SM	Ae	1	1			1	1						1				1					
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04/11/2005	11:59	38	1	Ca	SM	Ae	1		1	1		1						1				1					
04/11/2005	14:10	38	1	Ca	SM	Ag	1	1			1				g	1									1		
04/11/2005	14:22	38	1	Ca	SM	Ae	1	1			1	1						1			1						
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04/11/2005	14:33	38	1	Ca	SM	Ae	1	1		1		1						1				1				1	
10/11/2005	15:33	21	1	Ca	SM	Ae	1		1		1	1						1			1						
10/11/2005	15:42	21	1	Ca	SM	Ae	1		1	1		1						1			1						
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10/11/2005	16:01	38	1	Ca	SM	Ag	1	1		1		1						1				1				1	
10/11/2005	16:13	38	1	Ca	SM	Ag	1	1		1					g	1									1		
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14/11/2005	09:25	21	1	Ca	SM	Ag	?	1		1	1				g	1									1		
14/11/2005	09:25	21	1	Ca	SM	Ag	?	1		1	1	1						1					1			1	
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14/11/2005	09:54	2	1	C	MC	Ab	1	1		1					b	1							1				1
14/11/2005	10:10	2	1	C	MC	Ae	1	1		1	1							1		1	1						
14/11/2005	10:24					Ae			1		1	1					1						1				1

14/11/2005	10:38					Ab		1		1						b	1											1		1
14/11/2005	10:52	2	1	C	MC	Ae	1		1		1																			1
14/11/2005	11:06	2	1	C	MC	Ae	1	1			1					g	1											1		
14/11/2005	11:06	2	1	C	MC	Ae	1	1			1		1						1			1							1	
14/11/2005	11:17					Ae		1		1					1					1							1			
14/11/2005	11:26					Ae		1	1		1					a	1											1		
14/11/2005	11:50	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	12:00	2	1	C	MC	Ae	1	1			1					b	1											1		
14/11/2005	12:00	2	1	C	MC	Ae	1	1			1		1						1			1								
14/11/2005	13:59	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	14:06	2	1	C	MC	Ae		1	1		1																			
14/11/2005	14:25	2	1	C	MC	Ae	1		1		1		1						1			1								
14/11/2005	14:35	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	14:41	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	14:46	2	1	C	MC	Ae	?	1		1						V		1			1									?
14/11/2005	14:59	2	1	C	MC	Ae	1		1		1		1						1			1								
14/11/2005	15:11	2	1	C	MC	Ae	1		1	1			1						1			1								
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14/11/2005	15:56	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	16:07	2	1	C	MC	Ae	1		1	1			1						1			1								
14/11/2005	16:27	2	1	C	MC	Ae	1	1	1	1	1					b	1											1		
14/11/2005	16:27	2	1	C	MC	Ae	1	1	1	1	1		1						1			1							1	
14/11/2005	16:35	2	1	C	MC	Ae	1	1		1	?		1						1				1							
14/11/2005	16:48	2	1	C	MC	Ae	1		1	1			1						1			1								1
14/11/2005	17:01	2	1	C	MC	Ae		1		1				1				1			1									1
18/11/2005	09:38					Ae			1	1				1				1			1									1
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18/11/2005	10:04	21	1	Ca	SM	Ae	1		1	1			1						1			1								
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18/11/2005	11:31					?																								
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18/11/2005	15:19	21	1	Ca	SM	Ae	1		1	1						g	1											1		
18/11/2005	15:19	21	1	Ca	SM	Ae	1		1	1			1						1			1							1	
18/11/2005	15:35					A			1	1										1										1
18/11/2005	15:50	21	1	Ca	SM	Ae	1		1	1			1						1			1								
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18/11/2005	16:24	21	1	Ca	SM	Ae	1		1	1			1						1			1								
18/11/2005	16:51	21	1	Ca	SM	Ae	1		1	1			1						1			1								
18/11/2005	16:58					C	?	1	1	1	1					P	1									1				
17/10/2005	10:34					?																								
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17/10/2005	11:07	47	1	C	FC	Af	1		1	1					1			1						1						
17/10/2005	11:13	47	1	C	FC	Af	1	1			1					c	1											1		
17/10/2005	11:29	47	1	C	FC	Af	1	1			1		1						1			1								
17/10/2005	11:38	47	1	C	FC	Af	1		1	1			1						1			1								
17/10/2005	11:45	47	1	C	FC	Af	1		1	1			1						1			1								
17/10/2005	11:52	47	1	C	FC	Af	1	1	1		1		1						1			1								
17/10/2005	12:00	47	1	C	FC	Af	1		1	1			1						1			1								
17/10/2005	14:12	47	1	C	FC	Af		1			1																			
17/10/2005	14:23	47	1	C	FC	Af	1		1	1			1						1			1								
17/10/2005	14:35	47	1	C	FC	Af			1	1						V		1			1									
19/10/2005	09:39	47	1	C	FC	Af	1		1	1			1						1				1							
19/10/2005	09:57	47	1	C	FC	Af	1		1	1			1						1			1								
19/10/2005	10:05					Af		1		1						V		1			1									1
19/10/2005	10:16	47	1	C	FC	Af	1		1	1			1						1			1								
19/10/2005	10:25	47	1	C	FC	Af	1		1	1			1						1			1								
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19/10/2005	10:49					Af																								
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19/10/2005	11:20	47	1	C	FC	Af		1			1	1						1					1							
19/10/2005	11:31	47	1	C	FC	Af	1		1	1			1						1			1								
19/10/2005	14:51	47	1	C	FC	Af	1		1	1			1						1			1								

19/10/2005	15:00	47	1	C	FC	Af	1		1	1			1						1			1							
19/10/2005	15:20	47	1	C	FC	Af	1		1	1			1						1			1							
19/10/2005	15:36	47	1	C	FC	Af	1		1	1			1						1			1							
19/10/2005	15:52	47	1	C	FC	Af	1		1	1			1						1			1							
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26/10/2005	14:26	34	1	G	FC	Af	?	1			1	1							1					1					
26/10/2005	14:36	34	1	G	FC	Af	1		1	1			1						1				1						
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26/10/2005	14:47	34	1	G	FC	Af	?	1			1	1						1						1					
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04/11/2005	10:34					?																							
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04/11/2005	11:13	47	1	C	FC	Af	1	1			1					c	1										1		
04/11/2005	11:29	47	1	C	FC	Af	1	1			1		1						1			1							
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10/11/2005	16:55	34	1	G	FC	Af			1	1					1				1						1				

11/11/2005	14:28	47	1	C	FC	Af			1	1					1				1					1					
11/11/2005	14:33	47	1	C	FC	Af			1	1					1				1					1					
11/11/2005	14:37	47	1	C	FC	Af			1	1					1				1					1					
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11/11/2005	15:04	47	1	C	FC	Af			1	1									1					1					
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14/11/2005	10:12	34	1	G	FC	Af	1		1	1			1						1			1							
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14/11/2005	14:47	34	1	G	FC	Af	?	1			1	1						1					1						
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18/11/2005	10:37	47	1	C	FC	Af	1		1	1			1						1		1								
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17/10/2005	10:35	98	2	Ca	SM	Ag	1		1	1			1						1		1								
17/10/2005	11:01	98	2	Ca	SM	Ag	1		1	1			1						1			1							
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17/10/2005	11:15					Ag	1		1	1			1						1				1						
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17/10/2005	11:47	98	2	Ca	SM	Ag	1	1			1		1						1				1						
17/10/2005	11:53	98	2	Ca	SM	Ag	1	1	1		1					P	1									1			

17/10/2005	12:01	98	2	Ca	SM	Ag	1		1	1			1					1						1							
17/10/2005	14:13	38	1	Ca	SM	Ag	1		1	1			1						1				1								
17/10/2005	14:24	38	1	Ca	SM	Ag	1	1			1		1						1				1								
17/10/2005	14:36					Ag	1	1	1		1		1						1			1									
19/10/2005	09:40					Ag	?		1	1						V		1			1										1
19/10/2005	09:58					Ag			1	1						b	1												1		1
19/10/2005	10:08	98	2	Ca	SM	Ag	1		1	1			1						1			1									
19/10/2005	10:17	98	2	Ca	SM	Ag			1	1				1				1						1							1
19/10/2005	10:26					Ag		1			1				1			1							1						1
19/10/2005	10:38					Ag			1	1						P	1										1				1
19/10/2005	10:44					Ag			1	1						P	1										1				1
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19/10/2005	10:55					Ag		1		1				1				1						1						1	1
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19/10/2005	11:22					D																									
19/10/2005	11:33					Ag			1	1				1				1			1										1
19/10/2005	14:51	98	2	Ca	SM	Ag	1		1	1			1						1			1									
19/10/2005	15:04	98	2	Ca	SM	A	1		1	1				1					1						1						
19/10/2005	15:30	98	2	Ca	SM	Ag	1		1	1			1						1			1									
19/10/2005	15:37	95	1	C	AE	Ag	1	1	1	1	1					x	1												1		
19/10/2005	15:37	95	1	C	AE	Ag	1	1	1	1	1				1					1								1		1	
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19/10/2005	16:27	98	2	Ca	SM	Ag		1	1	1	1					c	1												1		1
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24/10/2005	15:43	38	1	Ca	SM	Ag	1		1		1					x	1												1		
24/10/2005	15:43	38	1	Ca	SM	Ag	1		1		1		1						1					1						1	
24/10/2005	15:50	38	1	Ca	SM	Ag	1		1	1						V		1			1										1
24/10/2005	16:03	38	1	Ca	SM	Ag	1		1	1						e	1												1		
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24/10/2005	16:15	38	1	Ca	SM	Ag	1		1	1			1						1					1						1	
24/10/2005	16:26	38	1	Ca	SM	Ag	1		1	1			1					1						1							1
24/10/2005	16:35	38	1	Ca	SM	Ag	1		1	1			1						1					1							
24/10/2005	16:43	38	1	Ca	SM	Ag	1		1	1			1						1					1							1
24/10/2005	16:51	38	1	Ca	SM	Ag	1		1	1						e	1												1		
24/10/2005	16:51	38	1	Ca	SM	Ag	1		1	1			1						1					1						1	
24/10/2005	16:59	38	1	Ca	SM	Ag	1		1	1						e	1												1		
24/10/2005	16:59	38	1	Ca	SM	Ag	1		1	1			1						1					1						1	
26/10/2005	09:29	21	1	Ca	SM	d	1		1	1						e	1												1		
26/10/2005	09:29	21	1	Ca	SM	d	1		1	1				1					1				1							1	
26/10/2005	09:40					Ag			1	1						P	1										1				1
26/10/2005	09:49					Ag		1		1						P	1										1				1
26/10/2005	09:49					Ag		1		1						V		1			1									1	1
26/10/2005	09:57					d		1			1					c	1												1		
26/10/2005	10:14	?	?	?	?	Ag	1		1	1			1						1					1							
26/10/2005	10:29	?	?	?	?	Ag	1		1	1			1					1						1							1
26/10/2005	10:41	?	?	?	?	Ag	1		1	1			1						1					1							
26/10/2005	10:56	?	?	?	?	Ag	1		1	1			1					1						1							
26/10/2005	11:09	2	1	C	MC	Ag			1		1					x	1												1		
26/10/2005	11:09	2	1	C	MC	Ag			1		1		1						1				1							1	
26/10/2005	11:22	2	1	C	MC	Ag	1		1	1	1					x	1												1		1
26/10/2005	11:22	2	1	C	MC	Ag	1		1	1	1		1						1				1							1	1
26/10/2005	11:30	2	1	C	MC	Ag	1		1	1			1					1					1								1
26/10/2005	11:55	?	?	?	?	Ag	1		1	1					1				1					1							
26/10/2005	12:01	?	?	?	?	Ag	1		1		1		1					1						1							1
26/10/2005	14:02	38	1	Ca	SM	Ag	1	1			1	1							1							1					
26/10/2005	14:08	38	1	Ca	SM	Ag	1		1	1					1				1						1						
26/10/2005	14:30	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	14:38	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	14:44	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	14:49	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	15:01	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	15:14	38	1	Ca	SM	Ag	1		1	1			1						1				1								
26/10/2005	15:48					Ag	1		1		1					b	1												1		
26/10/2005	15:48					Ag	1		1		1				1				1						1					1	
26/10/2005	16:00	38	1	Ca	SM	Ag	1		1	1						V		1			1										

26/10/2005	16:00	38	1	Ca	SM	Ag	1		1	1			1						1				1						
26/10/2005	16:09	38	1	Ca	SM	Ag			1		1					P	1									1			
26/10/2005	16:29					H																							
04/11/2005	10:22	98	2	Ca	SM	Ag	1		1	1			1						1		1								
04/11/2005	10:35	98	2	Ca	SM	Ag	1		1	1			1						1		1								
04/11/2005	11:01	98	2	Ca	SM	Ag	1		1	1			1						1			1							
04/11/2005	11:09	98	2	Ca	SM	Ag	1		1	1			1						1			1							
04/11/2005	11:15					Ag	1		1	1			1						1				1						
04/11/2005	11:31	21	1	Ca	SM	Ag	1	1	1	1	1					x	1										1		
04/11/2005	11:31	21	1	Ca	SM	Ag	1	1	1	1	1		1						1				1					1	
04/11/2005	11:31	21	1	Ca	SM	Ag	1	1	1	1	1				1				1						1			1	
04/11/2005	11:39	98	2	Ca	SM	Ag	1	1			1		1						1				1						
04/11/2005	11:47	98	2	Ca	SM	Ag	1	1			1		1						1				1						
04/11/2005	11:53	98	2	Ca	SM	Ag	1	1	1		1					P	1									1			
04/11/2005	12:01	98	2	Ca	SM	Ag	1		1	1			1					1					1						
04/11/2005	14:13	38	1	Ca	SM	Ag	1		1	1			1						1			1							
04/11/2005	14:24	38	1	Ca	SM	Ag	1	1			1		1						1			1							
04/11/2005	14:36					Ag	1	1	1		1		1						1		1								
10/11/2005	15:35	38	1	Ca	SM	Ag	1	1	1	1						V		1		1									
10/11/2005	15:43	38	1	Ca	SM	Ag	1		1		1					x	1										1		
10/11/2005	15:43	38	1	Ca	SM	Ag	1		1		1		1						1				1					1	
10/11/2005	15:50	38	1	Ca	SM	Ag	1		1	1						V		1		1									1
10/11/2005	16:03	38	1	Ca	SM	Ag	1		1	1						e	1										1		
10/11/2005	16:03	38	1	Ca	SM	Ag	1		1	1			1						1			1						1	
10/11/2005	16:15	38	1	Ca	SM	Ag	1		1	1						e	1										1		
10/11/2005	16:15	38	1	Ca	SM	Ag	1		1	1			1						1				1					1	
10/11/2005	16:26	38	1	Ca	SM	Ag	1		1	1			1					1					1						1
10/11/2005	16:35	38	1	Ca	SM	Ag	1		1	1			1						1				1						
10/11/2005	16:43	38	1	Ca	SM	Ag	1		1	1			1						1				1						1
10/11/2005	16:51	38	1	Ca	SM	Ag	1		1	1						e	1										1		
10/11/2005	16:51	38	1	Ca	SM	Ag	1		1	1			1						1				1					1	
10/11/2005	16:59	38	1	Ca	SM	Ag	1		1	1						e	1										1		
10/11/2005	16:59	38	1	Ca	SM	Ag	1		1	1			1						1				1					1	
14/11/2005	09:29	21	1	Ca	SM	d	1		1	1						e	1										1		
14/11/2005	09:29	21	1	Ca	SM	d	1		1	1				1					1			1						1	
14/11/2005	09:40					Ag			1	1						P	1									1			1
14/11/2005	09:49					Ag		1		1						P	1									1			1
14/11/2005	09:49					Ag		1		1						V		1		1								1	1
14/11/2005	09:57					d		1			1					c	1										1		
14/11/2005	10:14	?	?	?	?	Ag	1		1	1			1						1				1						
14/11/2005	10:29	?	?	?	?	Ag	1		1	1			1					1					1						1
14/11/2005	10:41	?	?	?	?	Ag	1		1	1			1						1				1						
14/11/2005	10:56	?	?	?	?	Ag	1		1	1			1					1					1						
14/11/2005	11:09	2	1	C	MC	Ag			1		1					x	1										1		
14/11/2005	11:09	2	1	C	MC	Ag			1		1		1						1			1						1	
14/11/2005	11:22	2	1	C	MC	Ag	1		1	1	1					x	1										1		1
14/11/2005	11:22	2	1	C	MC	Ag	1		1	1	1		1						1			1						1	1
14/11/2005	11:30	2	1	C	MC	Ag	1		1	1			1					1				1							1
14/11/2005	11:55	?	?	?	?	Ag	1		1	1					1				1				1						
14/11/2005	12:01	?	?	?	?	Ag	1		1		1		1					1					1						1
14/11/2005	14:02	38	1	Ca	SM	Ag	1	1			1	1							1						1				
14/11/2005	14:08	38	1	Ca	SM	Ag	1		1	1					1				1					1					
14/11/2005	14:30	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	14:38	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	14:44	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	14:49	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	15:01	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	15:14	38	1	Ca	SM	Ag	1		1	1			1						1			1							
14/11/2005	15:48					Ag	1		1		1					b	1										1		
14/11/2005	15:48					Ag	1		1		1				1				1					1				1	
14/11/2005	16:00	38	1	Ca	SM	Ag	1		1	1						V		1		1									
14/11/2005	16:00	38	1	Ca	SM	Ag	1		1	1			1						1				1						
14/11/2005	16:09	38	1	Ca	SM	Ag			1		1					P	1									1			
14/11/2005	16:29					H																							
18/11/2005	09:40					Ag	?		1	1						V		1		1									1
18/11/2005	09:58					Ag			1	1						b	1										1		1
18/11/2005	10:08	98	2	Ca	SM	Ag	1		1	1			1						1		1								
18/11/2005	10:17	98	2	Ca	SM	Ag			1	1				1				1					1						1
18/11/2005	10:26					Ag		1			1				1			1						1					1
18/11/2005	10:38					Ag			1	1						P	1									1			1
18/11/2005	10:44					Ag			1	1						P	1									1			1
18/11/2005	10:50					Ag			1	1						P	1									1			1
18/11/2005	10:55					Ag		1		1						P	1									1			1
18/11/2005	10:55					Ag		1		1				1				1					1					1	1

18/11/2005	11:14	38	1	Ca	SM	Ag	1	1	1	1	1							e	1										1		
18/11/2005	11:22					D																									
18/11/2005	11:33					Ag			1	1				1						1				1							1
18/11/2005	14:51	98	2	Ca	SM	Ag	1		1	1			1					1			1		1								
18/11/2005	15:04	98	2	Ca	SM	A	1		1	1				1				1							1						
18/11/2005	15:30	98	2	Ca	SM	Ag	1		1	1			1					1			1										
18/11/2005	15:37	95	1	C	AE	Ag	1	1	1	1	1							x	1										1		
18/11/2005	15:37	95	1	C	AE	Ag	1	1	1	1	1				1							1						1		1		
18/11/2005	15:54	98	2	Ca	SM	Ag	1		1	1			1					1			1										
18/11/2005	16:01	98	2	Ca	SM	Ag	1		1	1			1					1			1										
18/11/2005	16:09	98	2	Ca	SM	Ag	1		1	1			1					1			1										
18/11/2005	16:20	98	2	Ca	SM	Ag	1		1	1			1							1											1
18/11/2005	16:27	98	2	Ca	SM	Ag		1	1	1	1							c	1										1		1
18/11/2005	16:27	98	2	Ca	SM	Ag		1	1	1	1		1							1					1					1	1
18/11/2005	16:52	98	2	Ca	SM	Ag	1		1	1			1					1			1										
18/11/2005	17:04	98	2	Ca	SM	Ag	1	1	1	1	1		1					1						1							
18/11/2005	17:04	98	2	Ca	SM	Ag	1	1	1	1	1		1					1			1									1	

Table A-1 – Recording chart for information audit

Appendix B – Stimulus testing

The following appendix shows the analysis of each case study or innovation project in more detail. The following data can be made available for future research purposes on request to the author (T.J.Howard@bath.ac.uk), or supervisors (S.J.Culley@bath.ac.uk), (E.A.Dekoninck@bath.ac.uk). This will be subject to brief approval by the sponsoring company. Much of the information has been removed or censored due to commercial sensitivity. Instances in which material has been removed and replaced with less commercially sensitive material are designated by two stars (*….*).

B.1 Random External Stimuli (Polyrim)

The following section will take the reader through a particular case study in which some specifically chosen External stimuli was provided to the innovation team during a brainstorming session. These External stimuli were generated by randomly searching and selecting pictures from an Image repository on the Internet (stimuli tool type A). In this section details are given in terms of the project details, the free thinking brainstorm analysis, the idea-concept breakdown and the analysis of *beta*-ideas and the stimuli.

B.1.1 Project details

Number of members: 9

4 technical, 5 innovation (2 experienced, 3 inexperienced)

Business type: food can

Project type: generic

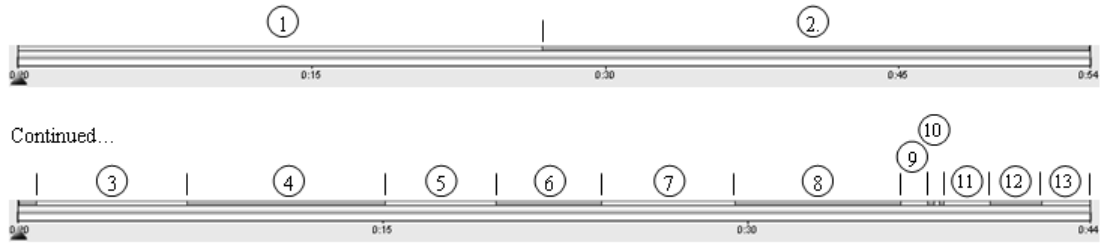
Mission statement: "To shortlist market opportunities and identify solutions for *a technology*"

Competitive advantage:

- To better the current container.
- Lower cost to produce than *competition* due to significantly reduced material wastage.
- The same ease of *function* as *competition*

– Possibility for added **functionality** on plastic ring.

Brainstorm timeline:



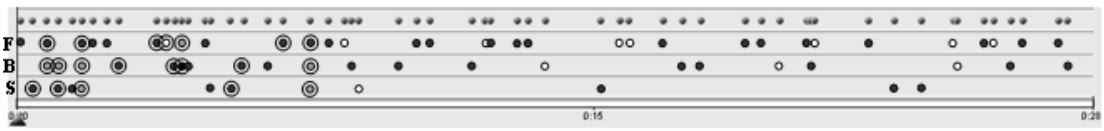
KEY

1 Opening discussion + briefing (33mins)
2 Free Brainstorming (34mins)
3 Stimulus 1 (6mins)
4 Stimulus 2 (8mins)
5 Stimulus 3 (5min)
6 Stimulus 4 (4mins)
7 Stimulus 5 (6mins)
8 Stimulus 6 (6min)
9 Stimulus 7 (1mins)
10 Stimulus 8,9 & 10 (1mins)
11 Stimulus 11 (2min)
12 Stimulus 12 (2mins)
13 Closing discussion (2mins)

When describing the task a hand a quote was taken from the project manager describing it as: "not only what markets it could be used for, but what it could do in those markets". This suggests the project is predominantly technology driven project requiring ideas of a functional nature.

B.1.2 Free brainstorm analysis

The plot below shows the idea log throughout the free thinking brainstorm session. The ideas were analysed to an additional depth to that stated in chapter 7 by suggesting whether the ideas related to function, behaviour or structure. This may be analysed and verified in further studies.



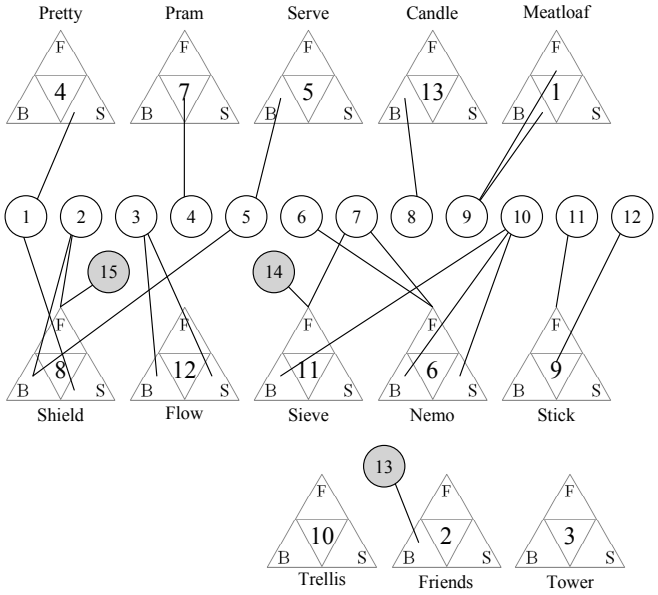
KEY

F – An idea predominantly involving/introducing a function
B – An idea predominantly involving/introducing a behaviour
S – An idea predominantly involving/introducing a structure

– Single idea
– An idea proposed at the stage gate meeting
– An idea recorded as a sketch during the brainstorm
– An idea not recorded during the brainstorm

B.1.3 Idea-Concept breakdown

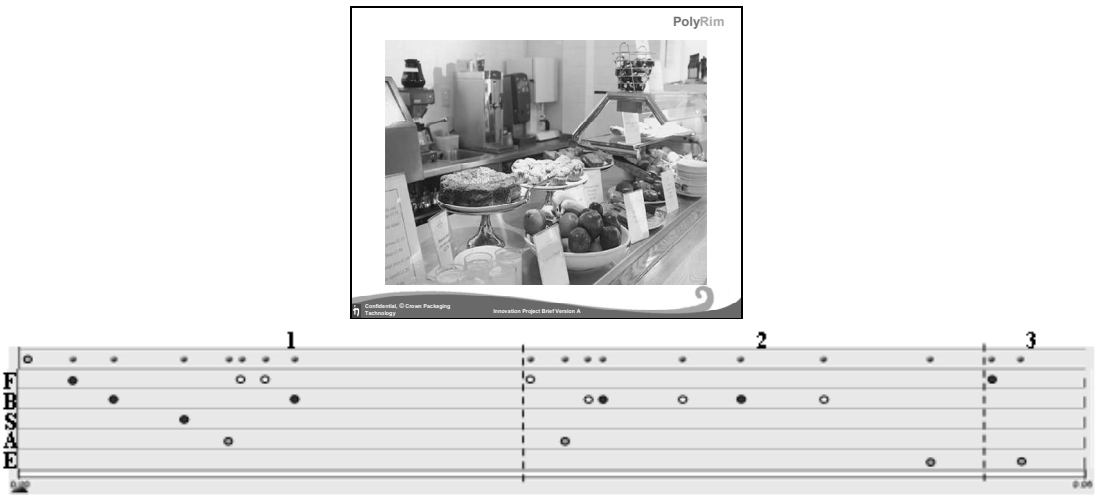
The diagram below described how the various ideas relate to the gate concepts.



B.1.4 Stimuli Analysis

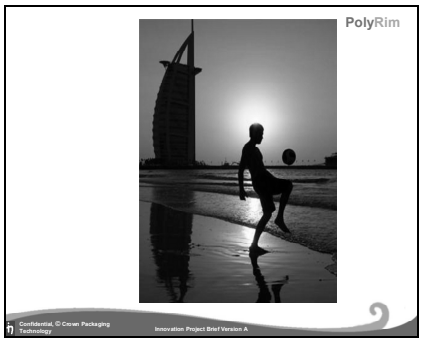
The following section describes each stimuli proposed and the *beta*-ideas in more detail. Several of the plots also included statements of analysis and evaluation, though these were not used in section 7.

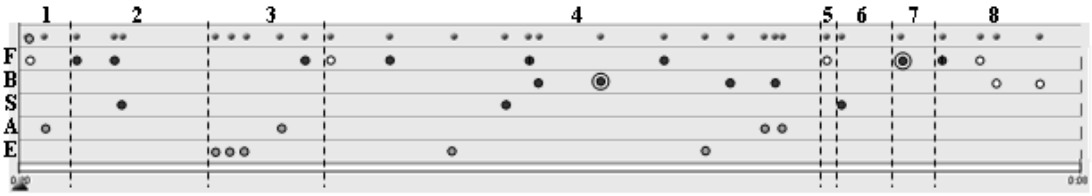
Random External Stimulus 1



It would appear that stimulus 1 directly inspired the ideas in section 1, at a functional level. In this case this lasted for 1.30mins of this timeline for this stimulus. During this section there were 3 functional ideas, 2 behavioural and 1 structural. The whole display lasted 6min.

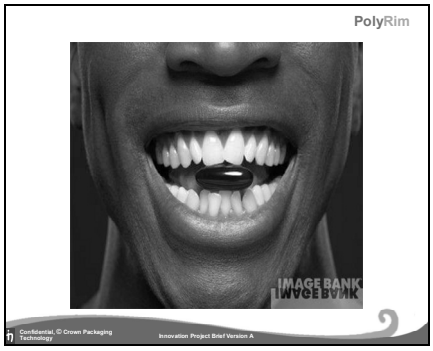
Random External Stimulus 2

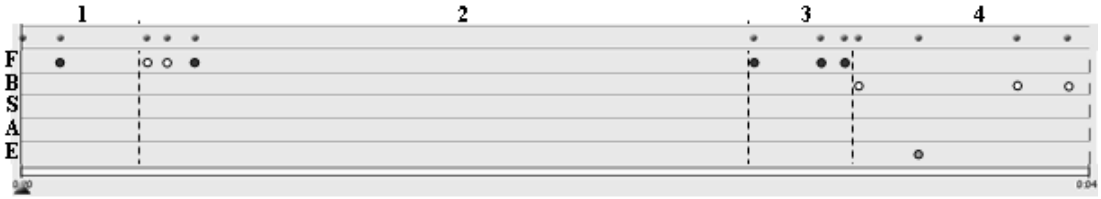




It would appear that stimulus 2 inspired the ideas in section 1, at a functional level with one level of abstraction (thinking of products associated with the beach). During this section there was only 1 functional idea. The section lasted just 30seconds. The stimulus was not explicitly referred to again with the exception of 1 idea in section 5. During this whole 8min display, 14 ideas were preserved and 6 un-preserved. One of these made it to the ideas stage gate.

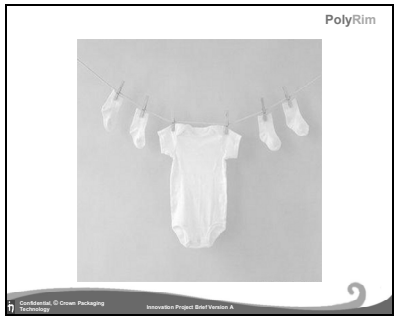
Random External Stimulus 3

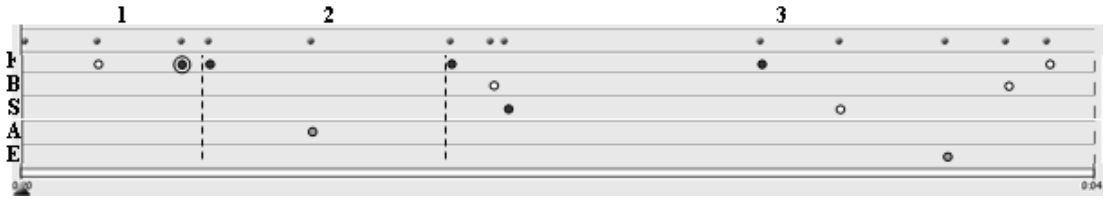




It would appear that stimulus 3 inspired the ideas in section 2, at a functional level. During this section there were 3 functional ideas. The section lasted around 2mins though much was taken by digression. The stimulus was not explicitly referred to again. During this whole 4min display, 5 ideas were preserved and 5 un-preserved.

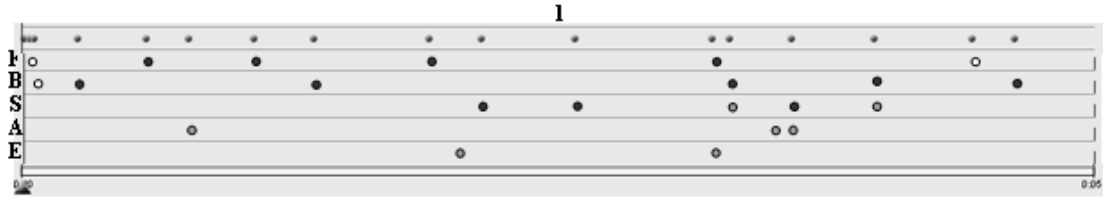
Random External Stimulus 4





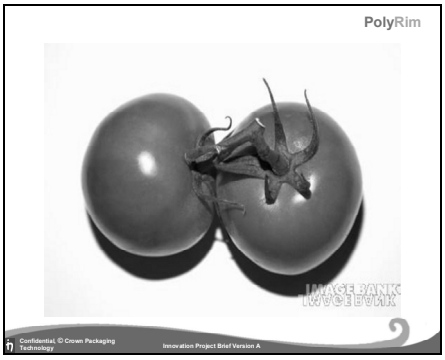
Stimulus 4 inspired the ideas in section 1, at a functional level with one level of abstraction (thinking of products associated with the picture). During this section there were 2 functional ideas. In section 3 the stimulus was referenced again to good effect string functional, behavioural and structural ideas together producing a relatively developed solution. During section 3 there were 3 functional, 2 behavioural and 2 structural ideas. During this whole 4min display, 5 ideas were preserved and 5 un-preserved. 1 idea was taken forward and developed at the gate.

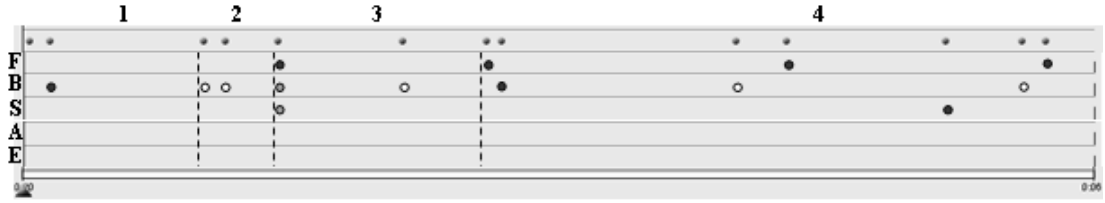
Random External Stimulus 5



Stimulus 5 inspired the ideas in section 1, at a behavioural level. During this section there were 15 ideas spread over all levels. Though the stimulus was not referenced again after the first 10 seconds, the behaviour derived from the stimulus provided a string of ideas each having knock-on effect on the next throughout the 5 minute display.

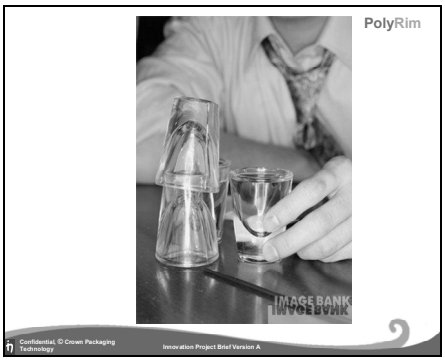
Random External Stimulus 6

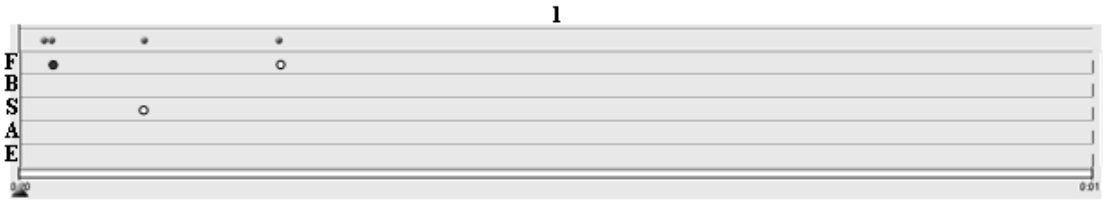




Stimulus 6 inspired the ideas in section 4, at a functional level. During this section there were two separate runs of ideas, the first of which being stimulated by functionality and the second with structure. The section lasted just over 3 mins. During this whole 6min display, 7 ideas were preserved and 5 un-preserved.

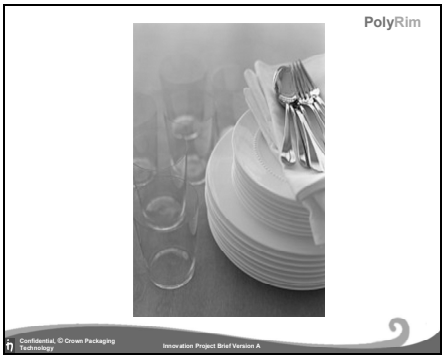
Random External Stimulus 7

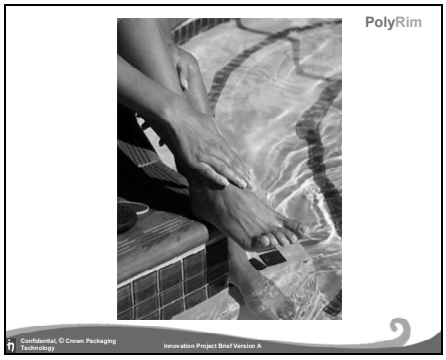




Stimulus 7 not really used, one idea stream produced by something seemingly unrelated. The section lasted 1minute consisting of 1 preserved idea and two supporting ideas that were not noted down.

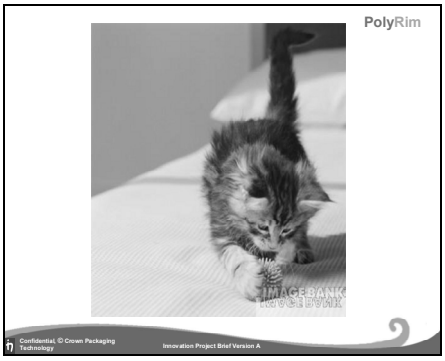
Random External Stimulus 8 and 9





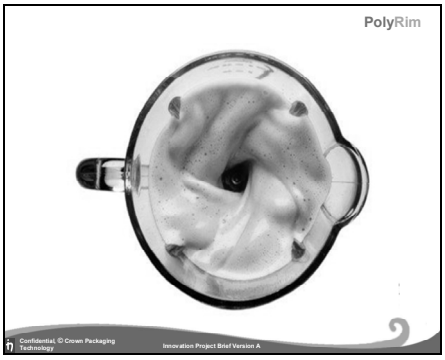
Stimuli 8 and 9 were only displayed for 30 seconds and stimulated no ideas.

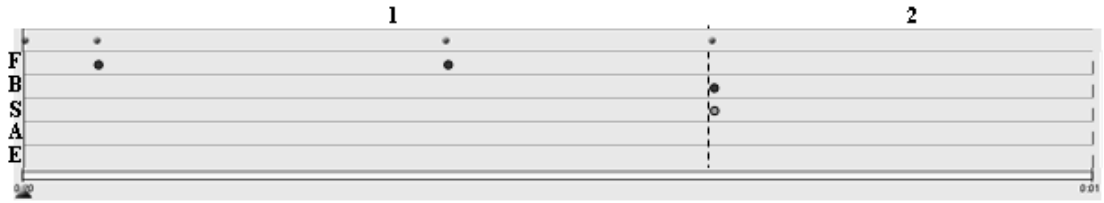
Random External Stimulus 10



Stimulus 10 inspired 1 functional assigned too 1 behavioural idea over the 14 second display.

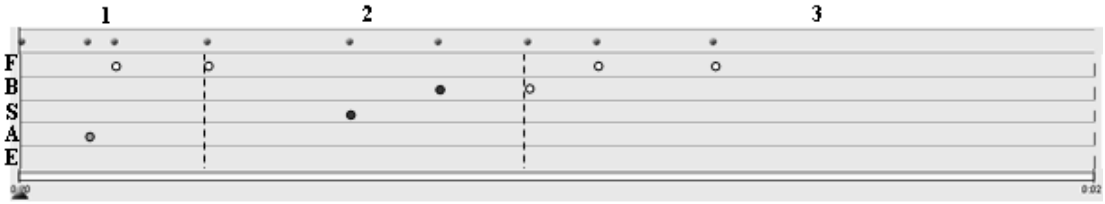
Random External Stimulus 11





Over the 2min time display 3 ideas were produced. The ideas in section 2 were directly stimulated at a functional level. A structure was assigned to the behavioural idea produced.

Random External Stimulus 12



Stimulus 12 helped produce 1 inappropriate idea at a very abstracted functional level in section 1. Stimulus 12 was not referenced again. During the whole display 7 were produced.

B.2 Guided External Stimuli (Blackbird)

The following section will take the reader through a particular case study in which some specifically chosen External stimuli was provided to the innovation team during a brainstorming session. These External stimuli were generated using the TRIZ contradiction matrix proposing inventive principles gained from other domains (stimuli tool type B). In this section details are given in terms of the project details, the free thinking brainstorm analysis, the idea-concept breakdown and the analysis of *beta*-ideas and the stimuli.

B.2.1 Project details

Number of members: 8

4 technical, 4 innovation (2 experienced, 2 inexperienced)

Business type: food can

Project type: customer

Mission statement: "To produce a new shape for *product* cans, which delivers a finished product to consumers that looks a more "*structure*" rather than *structure* *product*"

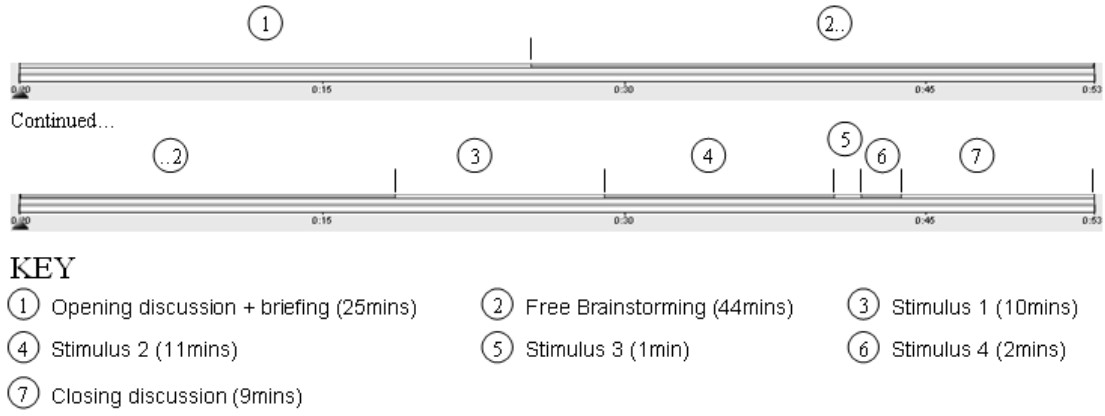
Competitive advantage:

The *product* provides a *function*, *structure* *product*

Details of product advantage…

The packaging *structure* will drive increased sales by bringing the pack into the 21st century, and giving the pack a *structure* that is more in keeping with the product

Brainstorm timeline:

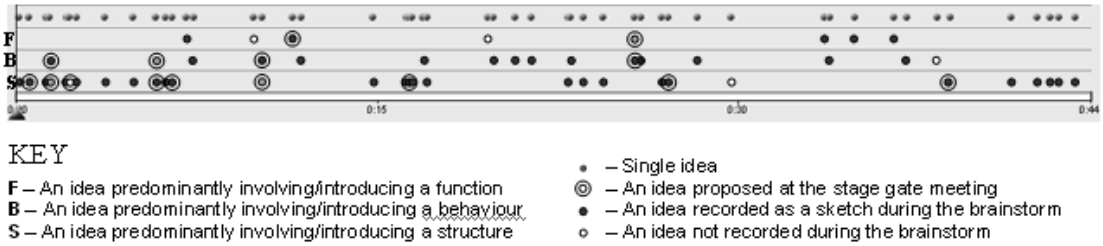


This project is a customer project so it is expected that the functions will already be set. Since the project is looking to simply evolve a current solution it can be predicted that many Original behavioural idea will not be of much use and the selected ideas will occur mostly on a structural and aesthetic level. This is backed up by the following statements captured during the brainstorming session: "What *customer* is expecting to see is 6 different shapes" and "Some of the ideas should be purely shape". Though it can be predicted that these statements regarding the brief will determine the structural nature of the ideas being produced, more importantly it is expected to have an even more noticeable effect for the idea selection.

In terms of a preconceived solution to this project the customer had already express a liking to two of the idea which progresses to the stage-gate s these involve existing technologies possessed by Crown Packaging Ltd.

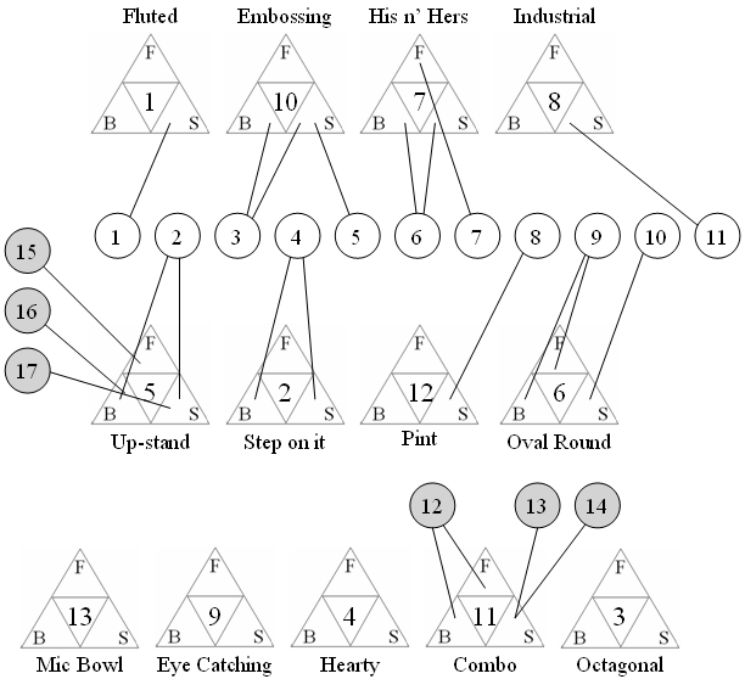
B.2.2 Free brainstorm analysis

The plot below shows the idea log throughout the free thinking brainstorm session. The ideas were analysed to an additional depth to that stated in chapter 7 by suggesting whether the ideas related to function, behaviour or structure. This may be analysed and verified in further studies.



During this 45 minute free thinking brainstorming session, 50 ideas were produced. As can be seen from the above plot, the majority of the ideas predominantly referred to the structure other solution. Interestingly it can be seen how the ideas taken through to the gate meeting were weighted to the beginning of the session. The first gate idea was a complete solution preconceived before the session. The second gate idea as a structural element of one gate solution and was again preconceived by the customer before the session. It must also be noted that the last two gate ideas refer to the behavioural and structural elements of the same solution.

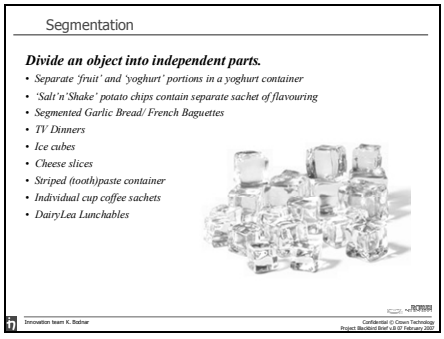
B.2.3 Idea-Concept breakdown

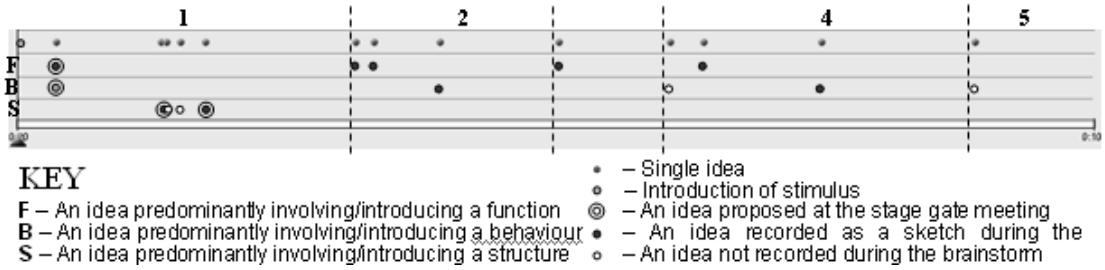


B.2.4 Stimuli Analysis

The following stimuli were generated by the use of the increasingly popular TRIZ tool, the contradiction matrix. In order to generate the appropriate principles the following contradiction was determined beforehand between the products shape and ease of manufacture. When putting these contradictory parameters into the matrix it retrieved the following inventive principles; segmentation, colour change, another dimension and mechanicals substitution. Each principle was displayed on a single slide and used as stimuli at the end of the brainstorm session.

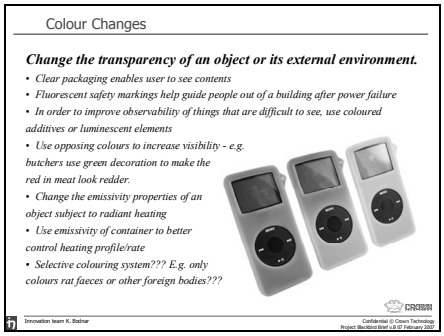
Guided External Stimulus 1

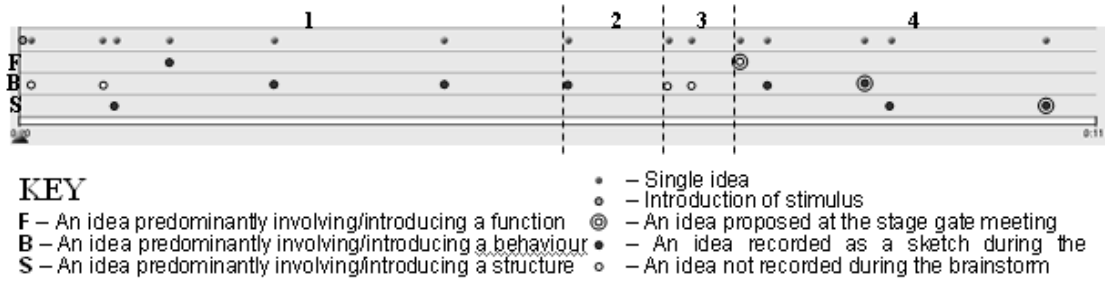




During its 10 minute display, 17 ideas were produced, one of which made it to the ideas gate meeting. The stimulus is related to behaviour but stimulated ideas of all types. Sections one two and three contained ideas which were clearly directly related to the stimulus, stages four and five had diverged from this. Two of the ideas were very evidently related to the stimulus from the protocol. They immediately preceded the reading aloud of the stimulus: "the obvious one is the segmented... TWO FLAVOURS OF *****!!!" followed later on by "Salt and shake… maybe you could open it and you could have a little sachet of ****** and ****". Judging by the protocol this was a particularly effective example.

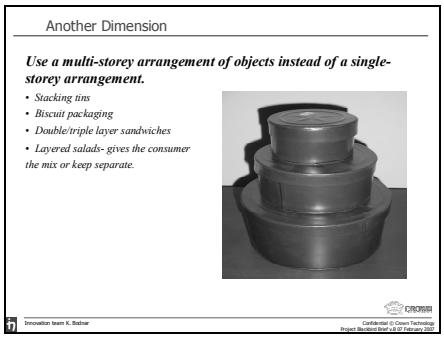
Guided External Stimulus 2





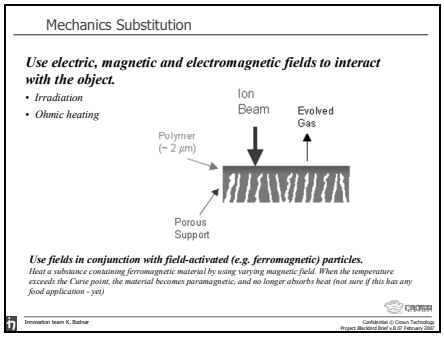
Stimulus 2 is again a behavioural based stimulus though each bullet point within the stimulus as proposes a function of the behaviour. The ideas produced in section 1 also followed this trend stating behavioural ideas with functions implied. After the initial 7 ideas followed a substantial lag of 3 minutes. Section 2 began a sting of ideas that continued to section four, though brief separated by another 2 ideas inspired by the stimulus. Throughout this whole 11 minute display 12 ideas were produced.

Guided External Stimulus 3



This stimulus is again on a behavioural level. The stimulus quickly inspired 1 idea that was discussed for the remainder of the display that lasted little over 1 minute. The stimulus was cut off prematurely, presumably due to lack of interest.

Guided External Stimulus 4



Stimulus 4 is also a behavioural. Throughout its 2 minute display it confused the members and was not understood "does anyone understand that?" However, discussion around its meaning did inspire talk of induction heaters, though nothing was proposed in the form of an idea.

B.2.5 Closing discussion

Once finishing generating ideas around the prescribed stimuli, the group members made several positive, qualitative comments firstly by clarifying that the session was productive "We've got loads more ideas then I thought we would". Several comments were also made regarding the effectiveness of the stimuli proposed:

- "They were all quite good I thought"

This comment seemed to reflect the designer's interest in the project rather than the effectiveness of the stimuli; as two of the four stimuli were only briefly entertained. Though this comment was not negative it lacks enough evidence or enthusiasm to support the usefulness of the stimuli.

- "If we'd have gone through those at the beginning we would have probably got these ideas quicker" and, "Certainly if you could show in advanced it has been quite useful"

This is a valid comment. The stimuli were introduced at this particular time to aid current brainstorming methods rather than drastically alter and risk damaging the free thought of participant from the offset. The effectiveness of the time of introduction of stimulus is therefore beyond the scope of this project but is an important proposition for research purposes. TRIZ style of thinking would argue that the theory is most effective if designers are guided through process and constrained to optimum solutions. In contrast, traditional brainstorming promotes free thinking and spontaneity.

- "The segmentation one certainly sparked a few ideas"

This is good and specific feedback though it is phrased negatively; stating one of the four stimulus slides sparked a few ideas. The analysis of the session confirms this statement, though only marginally from the 'colour change' stimulus.

B.3 Random Internal Stimuli (Warhol)

The following section will take the reader through a particular case study in which some chosen Internal stimuli was provided to the innovation team during a brainstorming session. These Internal stimuli were generated by randomly selecting concepts from within the projects database on the Crown shared drive (stimuli tool type C). In this section details are given in terms of the project details, the free thinking brainstorm analysis, the idea-concept breakdown and the analysis of *beta*-ideas and the stimuli.

B.3.1 Project details

Number of members: 9

4 technical, 5 innovation (2 experienced, 3 inexperienced)

Business type: beverage can

Project type: carrot

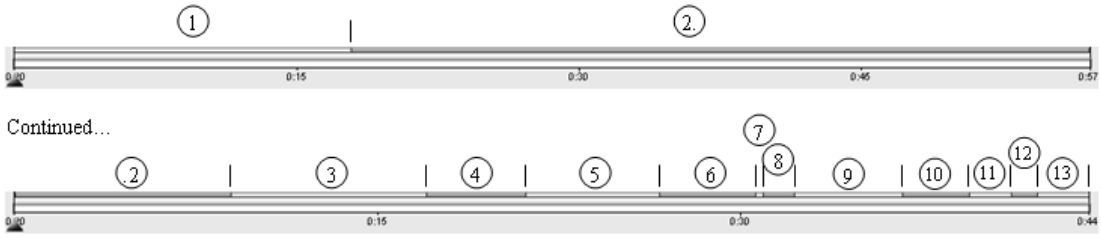
Mission statement: "To produce fresh ideas for packaging to help re-invigorate the *brand*"

Competitive advantage:

*Packaging solutions will increase brand loyalty to *brand* by:*

- Drawing more attention to the *brand*
- Encouraging increased consumption of the *brand* product(s)
- Encouraging consumption of *brand* on alternative occasions

Brainstorm timeline:

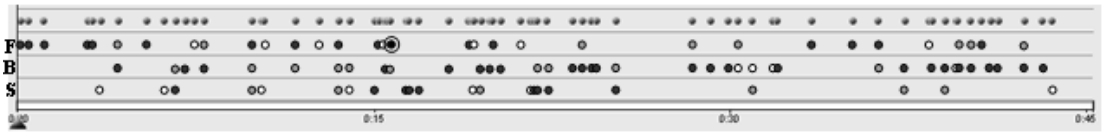


KEY

1. Opening discussion + briefing (18mins)
2. Free Brainstorming (48mins)
3. Stimulus 1 (8mins)
4. Stimulus 2 (4mins)
5. Stimulus 3 (6min)
6. Stimulus 4 (4mins)
7. Stimulus 5 (<1mins)
8. Stimulus 6 (1min)
9. Stimulus 7 (4mins)
10. Stimulus 8 (3mins)
11. Stimulus 9 (2min)
12. Stimulus 10 (1mins)
13. Closing discussion (2mins)

B.3.2 Free brainstorm analysis

The plot below shows the idea log throughout the free thinking brainstorm session. The ideas were analysed to an additional depth to that stated in chapter 7 by suggesting whether the ideas related to function, behaviour or structure. This may be analysed and verified in further studies.



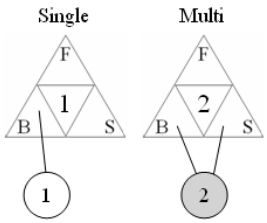
KEY

F – An idea predominantly involving/introducing a function
B – An idea predominantly involving/introducing a behaviour
S – An idea predominantly involving/introducing a structure

– Single idea
– An idea proposed at the stage gate meeting
– An idea recorded as a sketch during the brainstorm
– An idea not recorded during the brainstorm

Eventually only one idea was proposed to the customer which was purely structural. This can there be seen as a very digressive brainstorm where it may have been better to concentrate on structural elements of ideas.

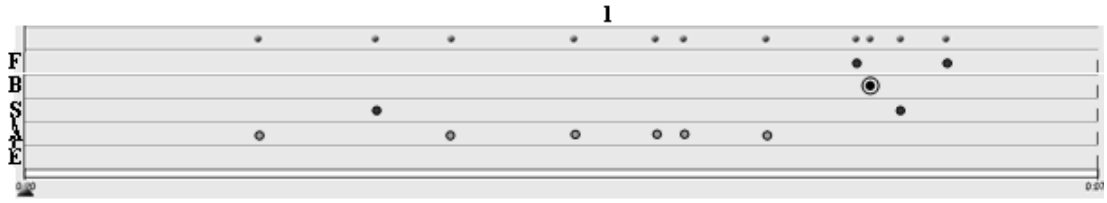
B.3.3 Idea-Concept breakdown



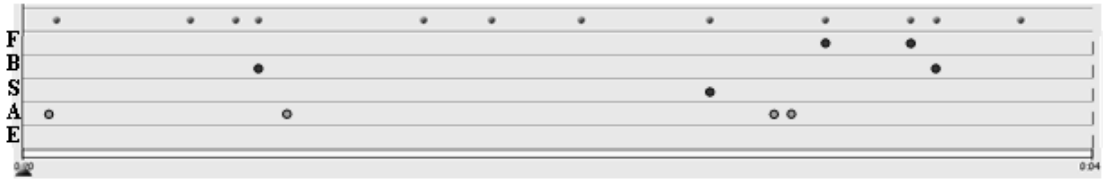
B.3.4 Stimuli Analysis

The following section describes the *beta*-ideas produced under each stimulus in a small amount more detail. As this was the last project to be analysed the methods were somewhat leaner which accounts for relatively small amounts of detail on each plot. Several of the plots also included statements of analysis and evaluation, though these were not used in section 7. The stimuli were removed due to confidentiality issues.

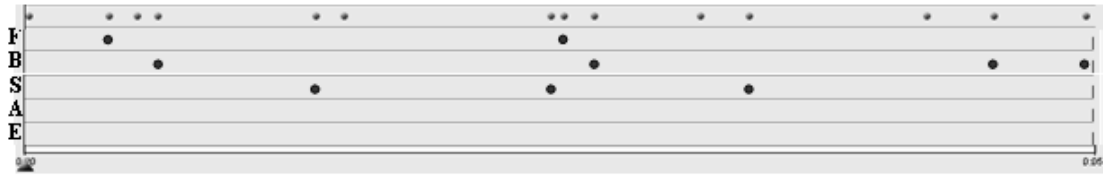
Random Internal Stimulus 1



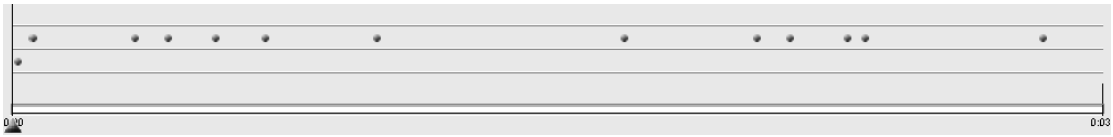
Random Internal Stimulus 2



Random Internal Stimulus 3



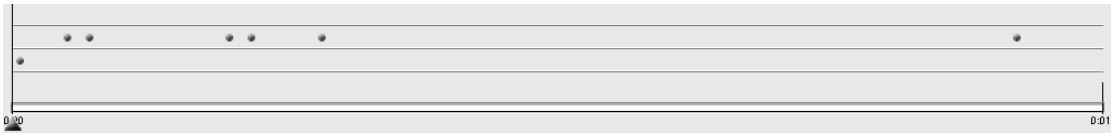
Random Internal Stimulus 4



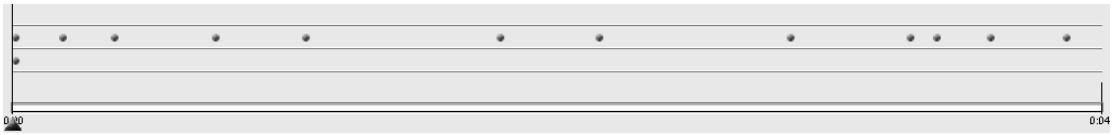
Random Internal Stimulus 5

Inspired no ideas and was disregarded very quickly.

Random Internal Stimulus 6



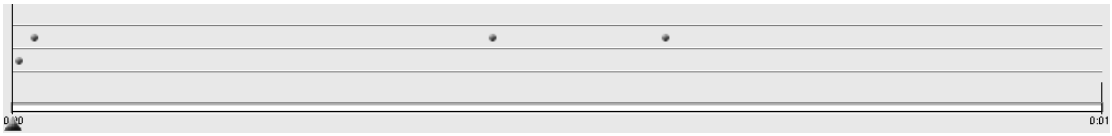
Random Internal Stimulus 7



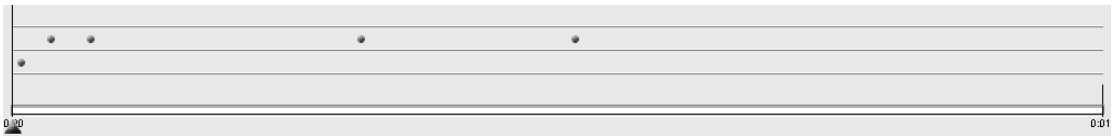
Random Internal Stimulus 8

Inspired no ideas and was disregarded very quickly.

Random Internal Stimulus 9



Random Internal Stimulus 10



B.4 Guided Internal Stimuli (Circus)

The following subsection will take the reader through a particular case study in which some specifically chosen stimuli generated from within the product domain, was provided to the innovation team during a brainstorming session. In this section details are given in terms of the project details, the free thinking brainstorm analysis, the idea-concept breakdown and the analysis of *beta*-ideas and the stimuli.

B.4.1 Project details

Number of members: 9

4 technical, 5 innovation (2 experienced, 3 inexperienced)

Business type: food can

Project type: carrot

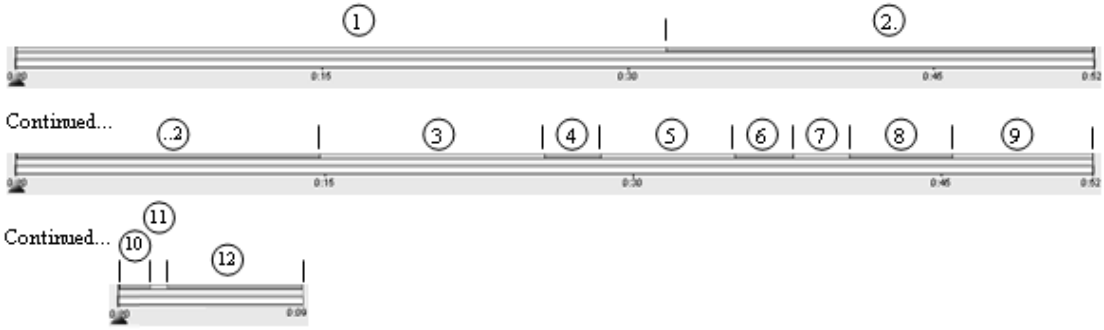
Mission statement: "To produce a container suitable for *product*"

Competitive advantage: *Target – to better the current container.*

- Better *function* (Need to *function* the container using *product*)
- *function*

- *structure*
- Lower cost if *behaviour* is used.

Brainstorm timeline:



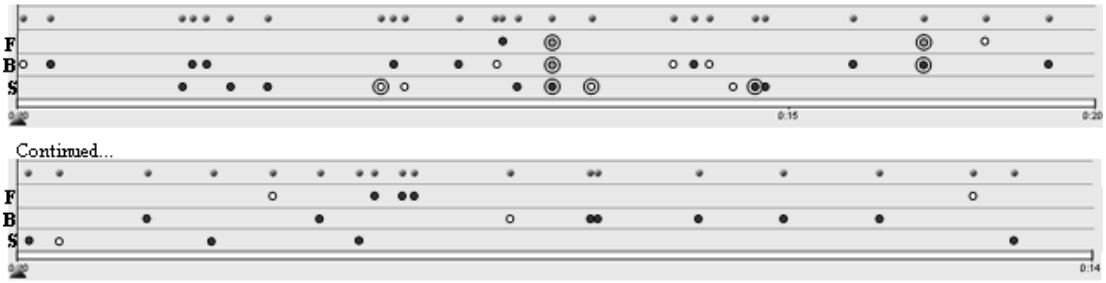
KEY

1 Opening discussion + briefing (33mins)
2 Free Brainstorming (34mins)
3 Stimulus 1 (11mins)
4 Stimulus 2 (3mins)
5 Stimulus 3 (6min)
6 Stimulus 4 (3mins)
7 Stimulus 5 (3mins)
8 Stimulus 6 (5min)
9 Stimulus 7 (6mins)
10 Stimulus 8 (2mins)
11 Stimulus 9 (1min)
12 Closing discussion (6mins)

This project is a carrot project where it is expected that the functions will be set to a lesser degree than customer projects enabling more divergence and ideas from all FBS levels. From the analysis of the transcription during the briefing session, several clues were provided as to the level of constraints of the project. It appears that the driver for the project was that the current packaging solution "wasn't designed for the occasion". This gives a slightly broader scope enabling designer to propose functions for the occasion.

This project had no preconceived solutions from either marketing or a customer.

B.4.2 Free brainstorm analysis

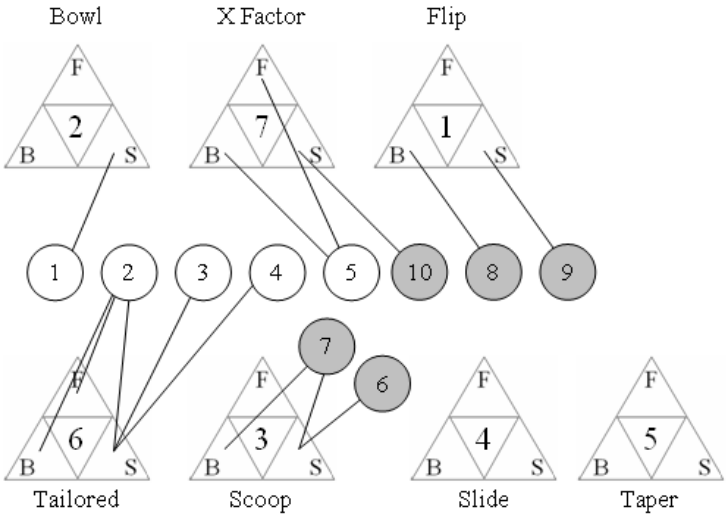


KEY

F – An idea predominantly involving/introducing a function
B – An idea predominantly involving/introducing a behaviour
S – An idea predominantly involving/introducing a structure

• – Single idea
◎ – An idea proposed at the stage gate meeting
● – An idea recorded as a sketch during the brainstorm
○ – An idea not recorded during the brainstorm

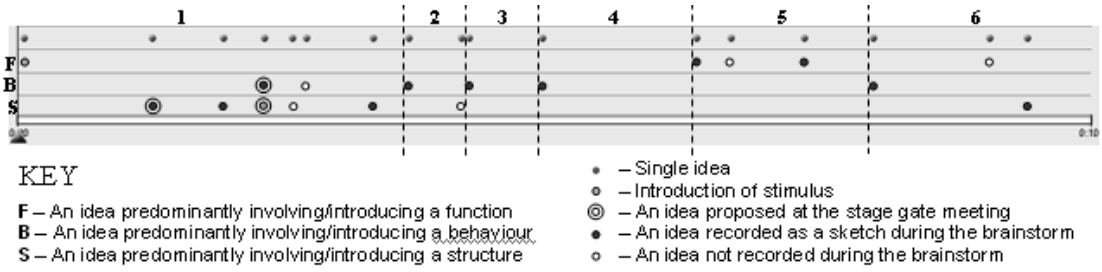
B.4.3 Idea-Concept breakdown



B.4.4 Stimuli Analysis

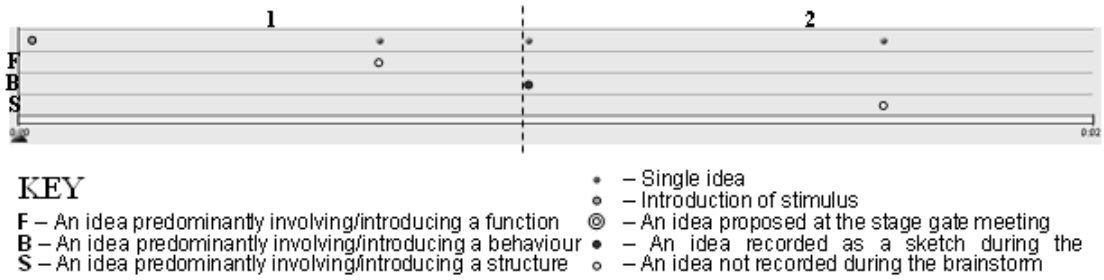
The following stimuli were generated by the use of the increasingly popular TRIZ tool, the contradiction matrix. In order to generate the appropriate principles the following contradiction was determined beforehand between the products shape and ease of manufacture. When putting these contradictory parameters into the matrix it retrieved the following inventive principles; segmentation, colour change, another dimension and mechanicals substitution. Each principle was displayed on a single slide and used as stimuli at the end of the brainstorm session.

Guided Internal Stimulus 1



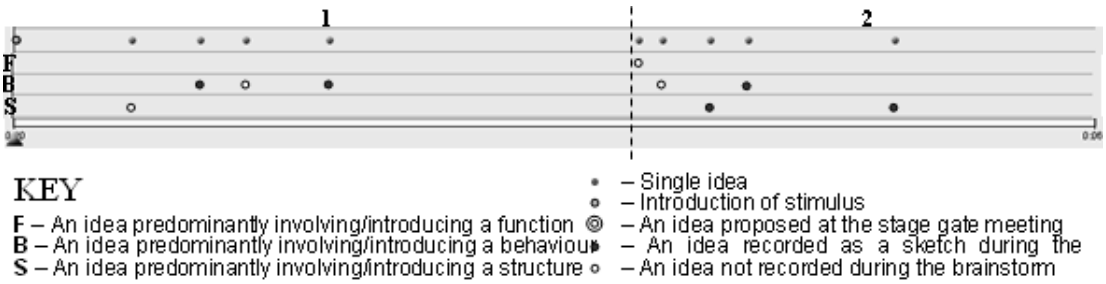
Stimulus 1 appeared to stimulated ideas on a structural level. The first idea of section 1 lead to a chain of 7 structural and behavioural ideas. After this section the stimulus was not reference again. During the whole 11min display 15 ideas were produce primarily at a structural level.

Guided Internal Stimulus 2



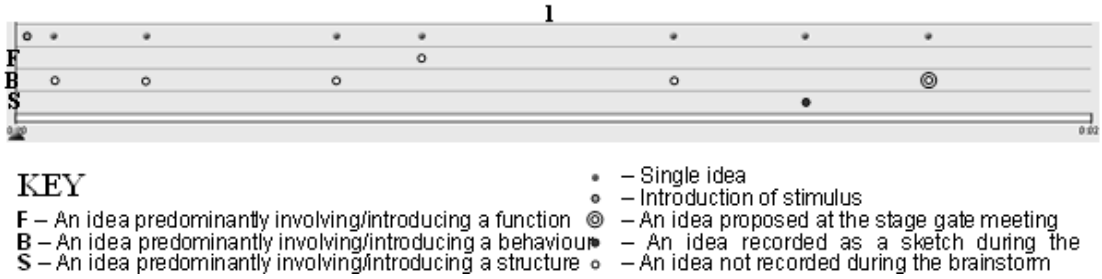
Stimulus 2 stimulated the 1 functional idea in section 1. In section 2 a behavioural idea was stimulated from the structure of the stimulus. During the 3min display there were only 3 ideas produced.

Guided Internal Stimulus 3



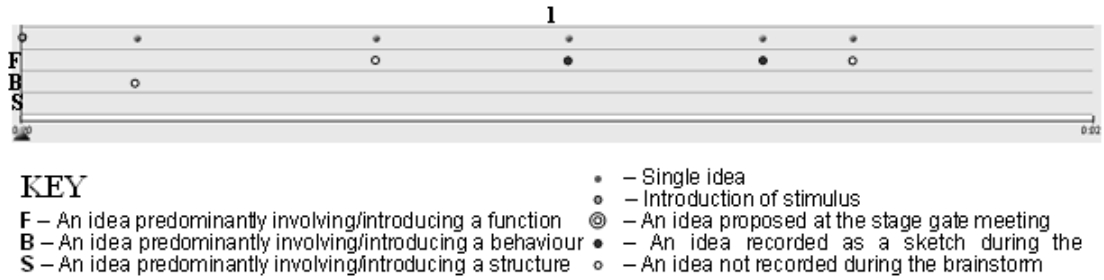
Stimulus 3 was judged from the offset "I think this is too detailed from where we are at the moment on this" though despite this, its behavioural qualities were extracted to form the first 3 ideas, though these ideas regarded the simple use of the companies existing technology. After further discussion idea stream 2 was created consisting of 5 idea, though it these cannot be directly attributed to the stimulus on display.

Guided Internal Stimulus 4



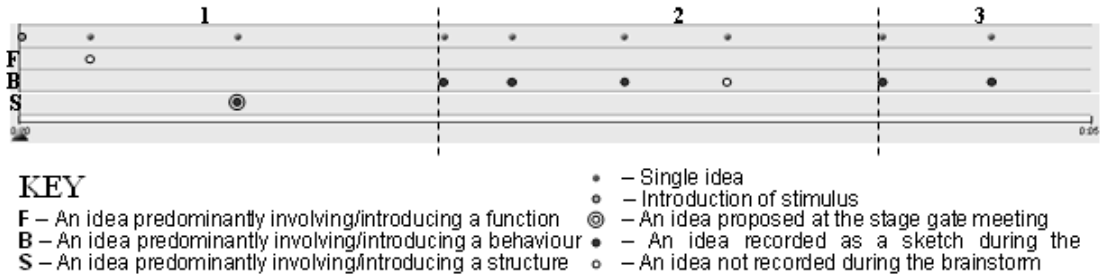
During the entire 3min display of stimulus 4 all the ideas 6 were of consequence of the behavioural aspects of the stimulus, though most of these were not captured. From analysing the protocol it can be assumed that the ideas were evaluated as inappropriate.

Guided Internal Stimulus 5



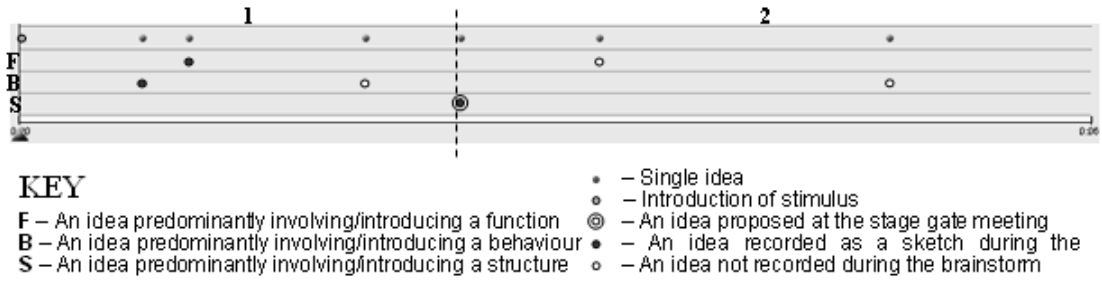
Stimulus 5 was an interesting case of what creative divergent thinking minds can produce from perhaps unapparently relevant stimulus. In this case a product was associated to the stimulus inspiring 4 functional ideas regarding "fizzy" or carbonated products. In one case the structure of the stimulus was misinterpreted to form a behavioural idea "Is it a pump action squirter?", "no but we could make it into that".

Guided Internal Stimulus 6



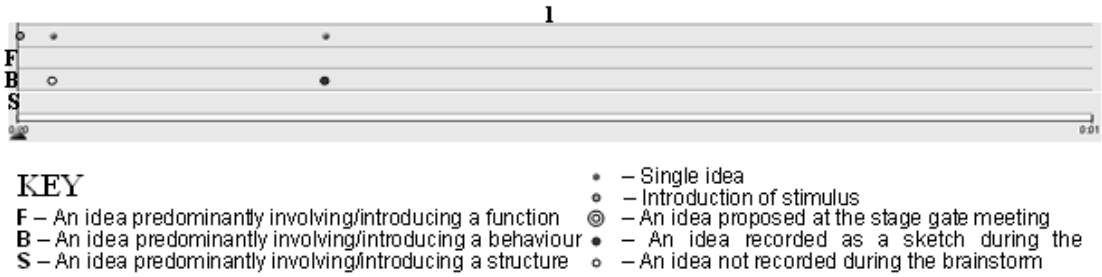
Stimulus 6 inspired the 2 ideas in section 1. The second section led on with similar ideas from the first though the video revealed that these ideas had been previously generated and thus were un-inspired by the stimulus on display. In section 3, 2 very divergent ideas were voiced; however, these had no direct link to the stimulus. During the 5 minute display 8 ideas were produced predominantly at the behavioural level.

Guided Internal Stimulus 7



In section 1 the 3 ideas were inspired by stimulus 7 at a behavioural level. Because this stimulus was so obviously pointing towards one idea, it inspired little divergence in ideas. Once moving into section two the ideas were very focused on structure (form and branding) producing some extremely important incites in the four statements of analysis. 7 ideas were produced during this 6 minute display.

Guided Internal Stimulus 8



Stimulus 8 shows the potential of using Internally generated concepts as a solution prompter rather that a stimulus prompter. In this case the consensus was that if it can be made this concept would be desirable. The first idea was a behavioural idea prompted by the structure of the stimulus.

Guided Internal Stimulus 9

This stimulus did not spark much enthusiasm, one member stating "I don't think this is relevant" before 1 behavioural idea, which was actually a repeat of an early idea. By this time a member were ready to leave.

B.4.5 Closing discussion

Once finishing generating ideas around the prescribed stimuli, the group members made several positive, qualitative comments firstly by clarifying that the session was productive "We've got loads more ideas then I thought we would". Several comments were also made regarding the effectiveness of the stimuli proposed:

** Q ** "The stimulus at the end was very good"
** Q ** "Very useful actually"
** Q ** "What's the purpose of that, then you think, then there's a secondary conversation that was quite productive actually"
** Q ** "Sometimes the secondary conversation isn't even linked to it, it's just got your mind thinking again

B.5 Standard Brainstorm 1 (Snus)

The following subsection will take the reader through a particular case study in which some no intervention or prepare stimuli is prescribed to the group members. In this section details are given in terms of the project details, the free thinking brainstorm analysis and the idea-concept breakdown.

B.5.1 Project details

Number of members: 6

6 innovation (3 experienced, 3 inexperienced)

Business type: spec pack

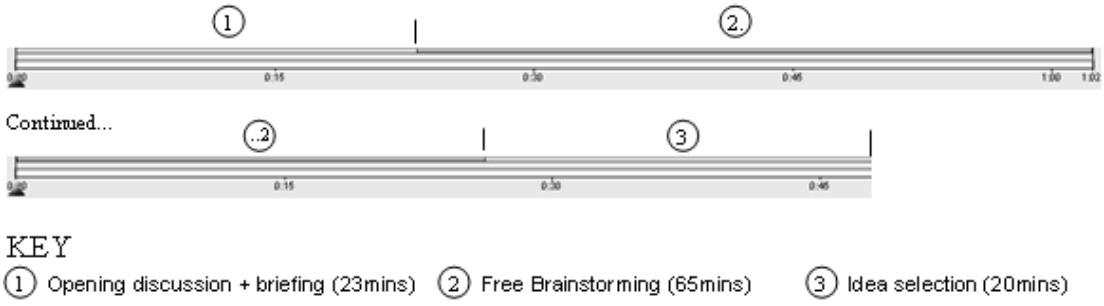
Project type: carrot

Mission statement: "To produce a container suitable for *product*"

Competitive advantage:

Target – to better the current container.

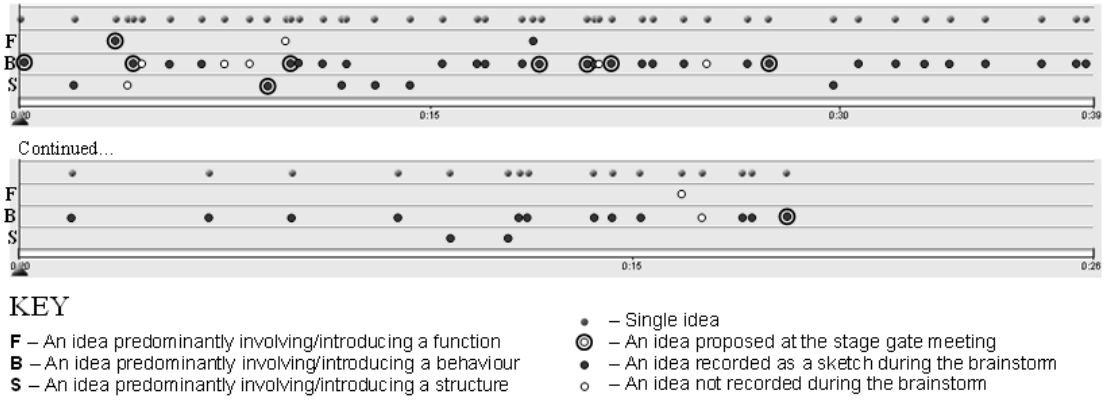
Brainstorm timeline:



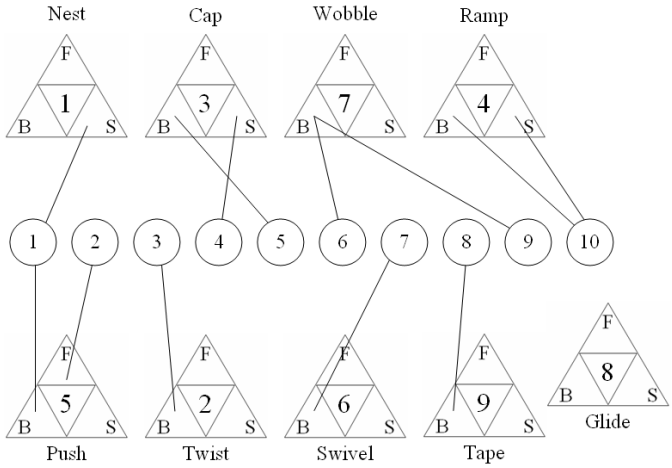
This project is a carrot project where it is expected that the functions will be set to a lesser degree than customer projects enabling more divergence and ideas from all FBS levels. However, in term of the brief and the final selection of ideas it is expected that the members will place more importance on behavioural aspects of ideas "The concentration should be on the mechanism - how it works".

This project had no preconceived solutions from either marketing or a customer.

B.5.2 Free brainstorm analysis



B.5.3 Idea-Concept breakdown



B.6 Other Brainstorms

The following projects were not analysed to the full extent. Though there was much learnt from these projects they had inconsistencies and gaps in data making them less comparable.

B.6.1 Standard brainstorm 2 (Dial)

Number of members: 7

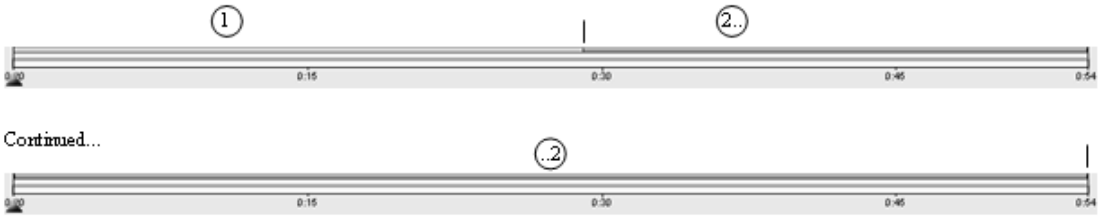
Business type: spec pack

Project type: carrot

Mission statement: "To produce a stylish and novel *technology for product"

Competitive advantage: *Premium imagine of metal*

Brainstorm timeline:



B.6.2 Standard brainstorm 3 (Smash)

Number of members: 6

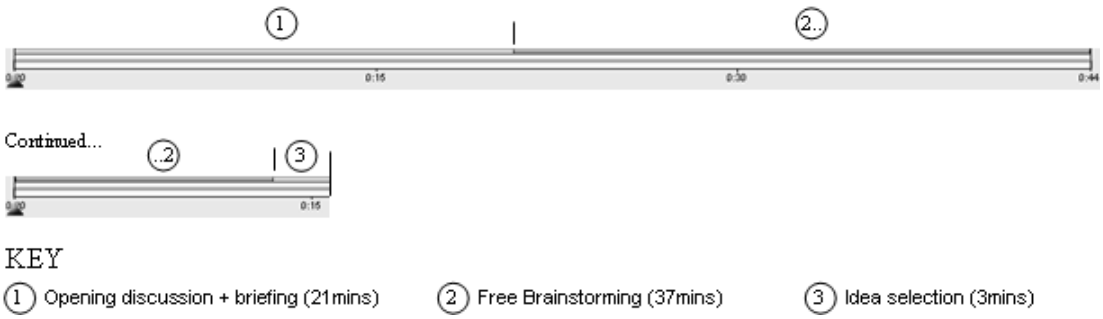
Business type: food can

Project type: customer

Mission statement:

Competitive advantage:

Brainstorm timeline:



B.6.3 Random word stimuli (Jumbo)

Number of members: 6

Business type: spec pack

Project type: carrot

Mission statement: "To produce a new container for *product* for *consumer*"

Competitive advantage: *Exciting and original. Novel portion sizes.*

Brainstorm timeline:

KEY

1 Opening discussion + briefing (4mins)
2 Free Brainstorming (30mins)
3 Stimulus 1 (5mins)
4 Stimulus 2 (3mins)
5 Stimulus 3 (4min)
6 Stimulus 4 (2mins)
7 Stimulus 5 (2mins)
8 Stimulus 6 (21min)
9 Stimulus 7 (5mins)
10 Closing discussion (2mins)

B.6.4 Special brainstorm (Beanstalk)

Number of members: 6

Business type: food can

Project type: customer

Mission statement: "To produce new convenient packaging solutions for the following **products**"

Competitive advantage: *Novelty and convenience.*

Brainstorm timeline:

KEY

1 Opening discussion + briefing (12mins)
2a Brief product 1 (2mins)
2b Brainstorm product 1 (25mins)
3a Brief product 2 (6mins)
3b Brainstorm product 2 (19min)
4a Brief product 3 (2mins)
4b Brainstorm product 3 (21mins)
5a Brief product 4 (3min)
5b Brainstorm product 4 (14mins)
6 Closing discussion (4mins)